HYDROGEOLOGY OF CIBOLA COUNTY, NEW MEXICO

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 94-4178

Prepared in cooperation with the
NEW MEXICO BUREAU OF MINES AND MINERAL RESOURCES
and the
NEW MEXICO STATE ENGINEER OFFICE

J.A. Baldwin and D.R. Rankin

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Albuquerque, New Mexico

1995

U.S. DEPARTMENT OF THE INTERIOR

BRUCE BABBITT, *Secretary*

U.S. GEOLOGICAL SURVEY

Gordon P. Eaton, *Director*

For additional information
write to:

District Chief
U.S. Geological Survey
Water Resources Division
4501 Indian School Rd. NE, Suite 200
Albuquerque, New Mexico 87110

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot	0.3048	meter
square foot	0.09290	square meter
foot squared per day	0.09290	meter squared per day
cubic foot	0.02832	cubic meter
cubic foot per second	0.02832	cubic meter per second
foot per mile	0.1894	meter per kilometer
gallon	3.785	liter
gallon per minute	0.06309	liter per second
gallon per minute per foot	0.2070	liter per second per meter
inch	25.4	millimeter
mile	1.609	kilometer
acre	0.4047	hectare
acre-foot	0.001233	cubic hectometer
square mile	2.590	square kilometer

Chemical concentrations are given only in metric units--milligrams per liter and micrograms per liter. Degrees Fahrenheit (°F) are converted to degrees Celsius (°C) as follows:

$$°C = 5/9\ (°F - 32)$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

The hydrogeology of Cibola County, New Mexico, was evaluated to determine the occurrence, availability, and quality of ground-water resources. Rocks of Precambrian through Quaternary age are present in Cibola County. Most rocks are sedimentary in origin except for Precambrian igneous and metamorphic rocks exposed in the Zuni Uplift and Tertiary and Quaternary basalts in northern and central parts of the county. The most productive aquifers in the county include (youngest to oldest) Quaternary deposits, sandstones in the Mesaverde Group, the Dakota-Zuni-Bluff aquifer, the Westwater Canyon aquifer, the Todilto-Entrada aquifer, sandstone beds in the Chinle Formation, and the San Andres-Glorieta aquifer.

Unconsolidated sand, silt, and gravel form a mantle ranging from a few inches to 150 to 200 feet over much of the bedrock in Cibola County. Well yields range from 5 to 1,110 gallons per minute. Dissolved-solids concentrations of ground water range from 200 to more than 5,200 milligrams per liter. Calcium, magnesium, bicarbonate, and sulfate are the predominant ions in ground water in alluvial material.

The Mesaverde Group mainly occurs in three areas of the county. Well yields range from less than 1 to 12 gallons per minute. The predominant ions in water from wells in the Mesaverde Group are calcium, sodium, and bicarbonate. The transition from calcium-predominant to sodium-predominant water in the southwestern part of the county likely is a result of ion exchange.

Wells completed in the Dakota-Zuni-Bluff aquifer yield from 1 to 30 gallons per minute. Dissolved-solids concentrations range from 220 to 2,000 milligrams per liter in water from 34 wells in the western part of the county. Predominant ions in the ground water include calcium, sodium, sulfate, and bicarbonate. Calcium predominates in areas where the aquifer is exposed at the surface or is overlain with alluvium.

Sandstones in the Chinle Formation yield from 10 to 300 gallons per minute to wells in the Grants-Bluewater area. In the western part of the county, sodium and bicarbonate predominate in water from the Chinle Formation. In the eastern part of the county, water quality is more variable than elsewhere and the predominant constituents include calcium, sodium, sulfate, and chloride.

Well yields from the San Andres-Glorieta aquifer in the Grants-Bluewater area are as much as 2,830 gallons per minute, whereas the maximum recorded pumping rate from the aquifer in other areas of the county is 88 gallons per minute. Dissolved-solids concentrations of ground-water range from about 130 to 4,200 milligrams per liter, and the water generally is a calcium bicarbonate sulfate type.

INTRODUCTION

Cibola County has a variety of ground-water systems and levels of development of ground-water resources. Ground-water resources in the north-central part of the county have been extensively developed for irrigation, uranium mining and milling, and municipal water supplies for the municipalities of Grants, Milan, Bluewater, and San Rafael (fig. 1). Ground-water use on the Pueblos of Acoma and Laguna has increased over the years as the population has increased. A well field for a coal-fired electrical-generating plant in Apache County, Arizona, adjacent to western Cibola County, withdraws large volumes of ground water from the San Andres-Glorieta aquifer. A coal-fired electrical-generating plant under construction in McKinley County, New Mexico, adjacent to north-central Cibola County, also will require large volumes of ground water from the same aquifer. A surface coal mine is planned in north-central Catron County, adjacent to and south of Cibola County. Cibola County residents face an increasing demand for water. Ground water is the primary source for domestic use, and there is concern about water availability for the future. In response to this concern, the U.S. Geological Survey in cooperation with the New Mexico Bureau of Mines and Mineral Resources and the New Mexico State Engineer Office began a study to evaluate the occurrence, availability, and chemical quality of ground water in areas of Cibola County not previously assessed.

Purpose and Scope

The purpose of this report is to describe the lithology and areal extent of the various rock units and the occurrence, availability, and chemical quality of ground water in Cibola County. Data collected in the field during 1980-86 for this report include location, owner, depth, casing diameter, completion date, water use, water level, and altitude of 244 wells and springs throughout Cibola County. Selected wells were revisited in the area between Grants and Bluewater to update information collected by Gordon (1961). Water-quality analyses were performed in samples from 144 of these wells and springs. These data supplement the geologic and hydrologic information collected by previous authors, which is widely used in this report.

Description of Study Area

Cibola County, in west-central New Mexico (fig. 1), was officially established as the 33d county in New Mexico on June 19, 1981. The new county was created from the western three-fourths of Valencia County and has an area of about 4,440 square miles. The town of Grants is the county seat. The principal population centers of Cibola County (Grants, San Rafael, Bluewater, Laguna, and Milan) are along Interstate 40 (fig. 1). The communities of Paguate, Bibo, and Seboyeta are north of Laguna. The Pueblo of Acoma is southeast of Grants, and the community of Fence Lake is in the southwestern part of the county.

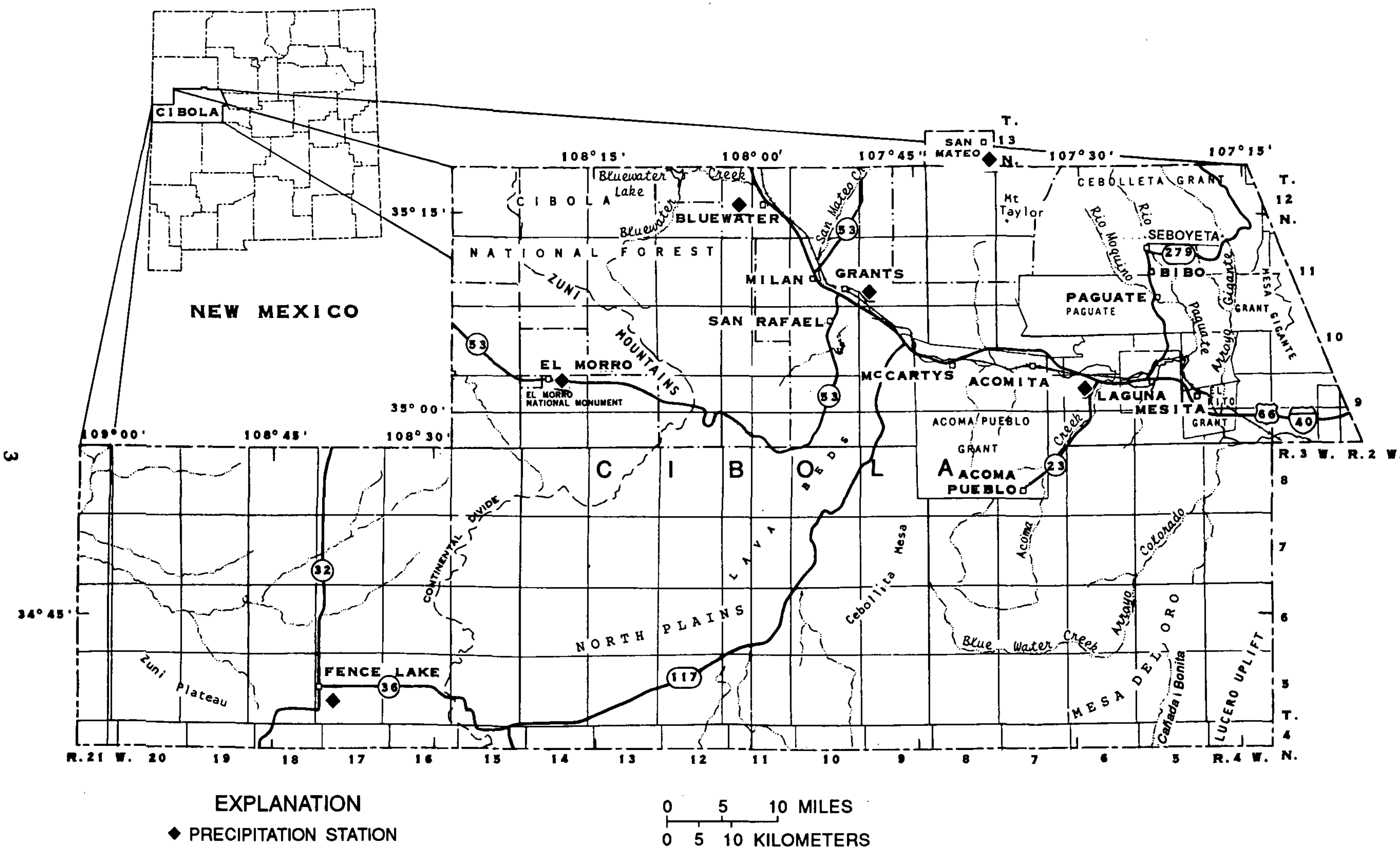


Figure 1.--Location of the study area, Cibola County, New Mexico.

Cibola County is situated between the mountainous regions of northern Catron and Socorro Counties to the south and the San Juan Basin to the north. South of the Zuni Mountains the Continental Divide crosses the North Plains, a high, basalt-covered plateau. East of the North Plains on the Pueblos of Acoma and Laguna, basalt- and sandstone-capped mesas are the most common landforms. Headward erosion has produced sheer-walled valleys that have 300 to 400 feet of relief in some areas. Gently rolling hills are found south of the Zuni Mountains and west of the Continental Divide. The Zuni Plateau forms an escarpment in the southwestern part of the county. Volcanic features include numerous cinder cones and shield volcanoes along the Continental Divide, a basalt flow southeast of Grants estimated to be 400 to 1,000 years old, and lava tubes, one of which contains a year-round deposit of ice (Maxwell, 1982, p. 300).

The Continental Divide extends roughly north to south through the western part of the county (fig. 1). West of the divide, surface-water drainage is toward the Little Colorado River in Arizona, whereas east of the divide surface-water drainage is toward the Rio Grande. Major topographic features include the Zuni Mountains and Mount Taylor in the north-central part of the county. The highest point in the Zuni Mountains is Mount Sedgwick, which has an altitude of 9,256 feet; the highest point in Cibola County is Mount Taylor, which has an altitude of 11,301 feet. The lowest point is about 5,460 feet, where the Rio San Jose crosses the eastern border of the county (pl. 1).

Precipitation at stations west of the Continental Divide (El Morro and Fence Lake) generally is greater than precipitation at stations east of the divide (Laguna, Grants, Bluewater, and San Mateo) (fig. 2). Station altitudes west of the divide generally are higher than those east of the divide and this may account for the greater average annual precipitation. The location of precipitation stations is shown in figure 1.

Methods of Investigation

The geology and hydrology of Cibola County were evaluated through the use of existing information supplemented by onsite data collection conducted during 1980-82. Existing data were used to help describe the geologic setting, structure, history, and ground-water resources of Cibola County. Extensive use was made of data collected by Foster (1957 and 1971) to describe the geology of the Zuni Mountains and to construct a structure contour map of Precambrian strata. The information collected by Gordon (1961) was used to characterize the geology, ground-water resources, and aquifer characteristics of the north-central portion of Cibola County. Data from files maintained by the New Mexico State Engineer Office and the New Mexico Bureau of Mines and Mineral Resources were compiled; well drillers, private landowners, and various companies also contributed data. U.S. Geological Survey topographic maps at scales of 1:24,000 and 1:62,500 were used to determine altitudes of wells and springs.

Onsite data collected during 1980-86 for this investigation include location, owner, depth, casing diameter, completion date, water use, water level, and land-surface altitude of each well and spring inventoried. Well depth and water levels were measured with a steel tape. Field values of specific conductance, pH, temperature, and alkalinity were determined using the procedure described by Wood (1976). Samples from 144 wells and springs were analyzed for major chemical constituents.

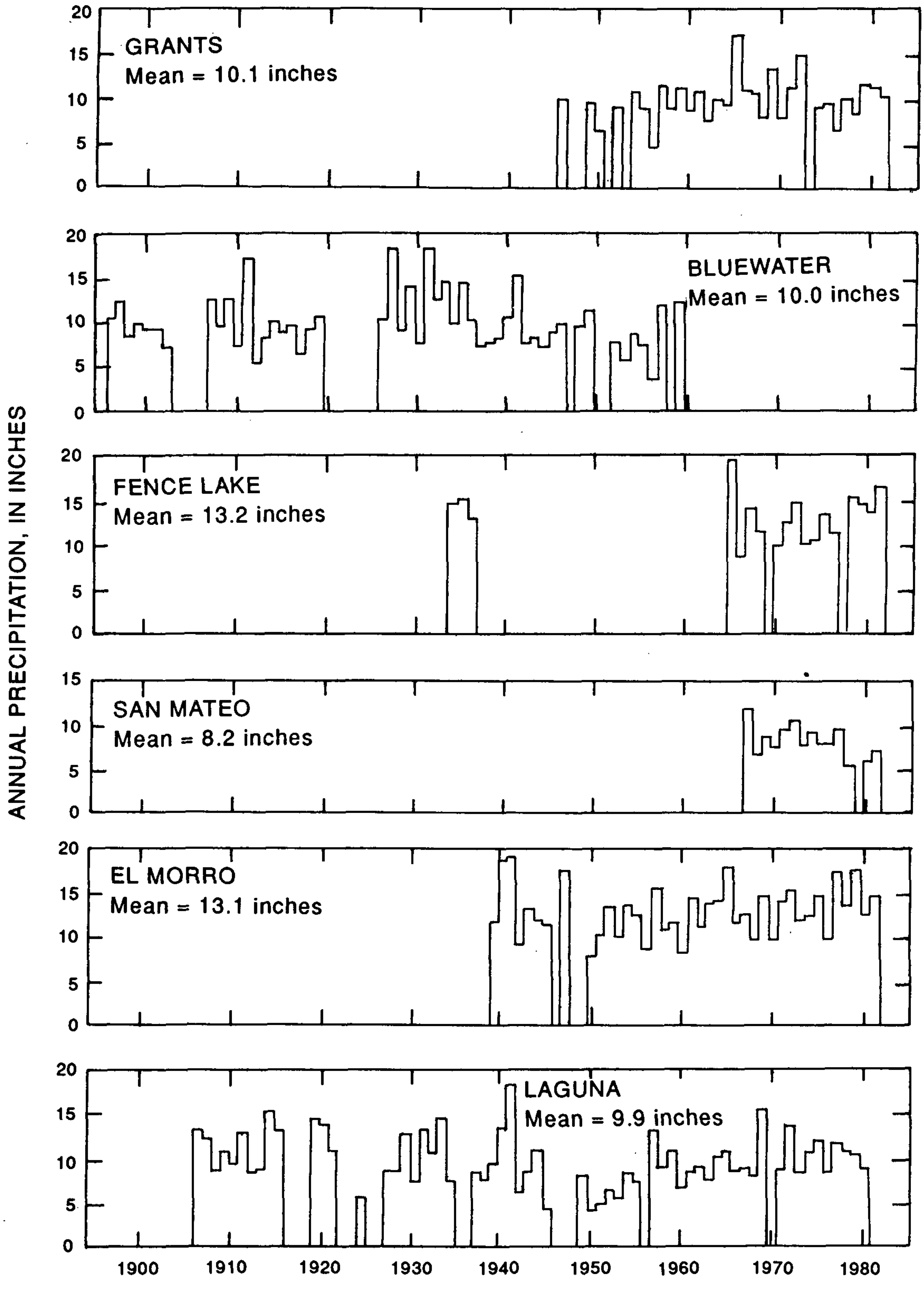


Figure 2.--Long-term precipitation records for stations in Cibola County, New Mexico (location of stations shown in figure 1).

Well-Numbering System

The system of numbering wells and springs in this report, used by the Geological Survey and the New Mexico State Engineer Office, is based on the common subdivision of public lands into sections. The well number, in addition to designating the well, locates its position to the nearest 10-acre tract in the land network. In this report, the first number denotes the township north of the New Mexico Base Line, the second denotes the range west of the New Mexico Principal Meridian, and the third denotes the section in which the well is located. The fourth number locates the well within the section to the nearest 10 acres by the system of quartering shown in figure 3. If two or more wells or springs are in the same 10-acre tract, they are distinguished by letters (a, b, and so forth) following the location number. The use of zeros in the fourth segment of the location number indicates that the well or spring could not be located accurately. Well number 07.15.12.400 would indicate that the well could not be located more accurately than the southeast quarter of section 12.

Parts of Cibola County have not been subdivided by township, range, and section. Location numbers for such areas were determined by extending section lines from adjacent areas.

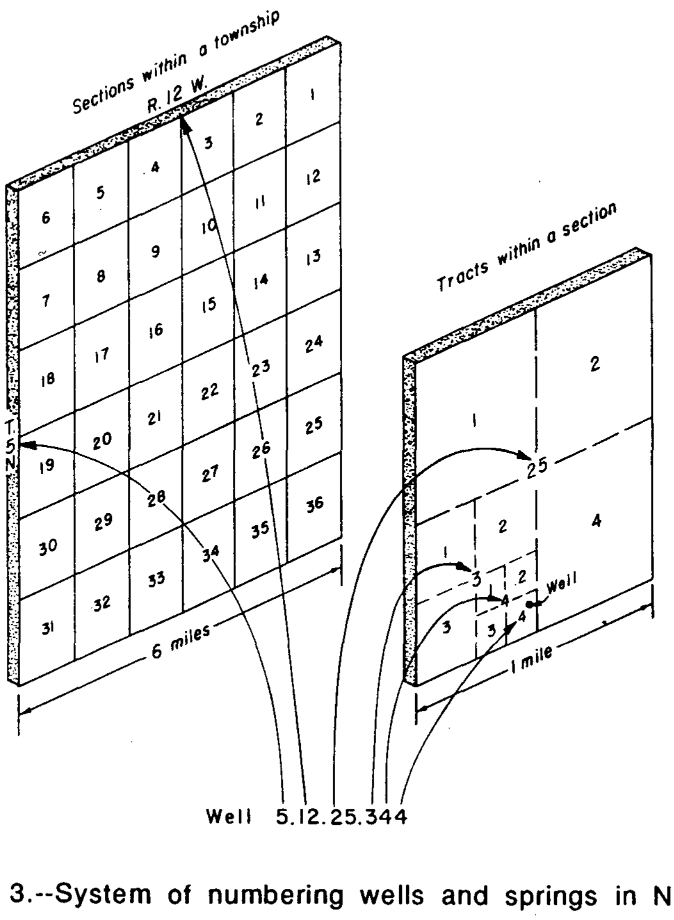


Figure 3.--System of numbering wells and springs in New Mexico.

Previous Investigations

One of the earlier reports to include ground-water information for Cibola County was prepared by Waring and Andrews (1935). This reconnaissance study covered northwestern New Mexico and included depth-to-water, temperature, and water-quality information for several wells in the western half of the county.

Morgan (1938) conducted a reconnaissance of ground water in the Rio San Jose-Bluewater area near Grants. In his report he described the geology and hydrology of the area. Murray (1945) also made a reconnaissance of ground water in the area near Bluewater. He identified three aquifers in the area (the basalt, the alluvium underlying the basalt, and Permian limestone and sandstone) as potential sources of ground water for irrigation. With the advent of irrigation and uranium mining and milling, large volumes of water were withdrawn from these aquifers. On May 21, 1956, the New Mexico State Engineer Office declared the Bluewater Basin an underground water basin (fig. 4), bringing the appropriation of ground water under the control of the State Engineer (New Mexico State Engineer Office, 1966). Gordon (1961) conducted a study to evaluate the quality and quantity of ground water and declining water levels in the Grants-Bluewater area. Titus (1963), in a report on ground water in eastern Valencia County, included water-level and water-quality data for wells in present eastern Cibola County.

Rapp (1960) conducted a reconnaissance study to determine the physical characteristics and hydrologic properties of the geologic formations on Indian lands in the county. The focus of the study was ground water because it was needed as a supplement to surface-water supplies for irrigation.

With increasing population and per capita use of water on the Acoma and Laguna tribal lands, detailed hydrologic studies were needed. Dinwiddie and Motts (1964) reported the results of test drilling and aquifer testing in parts of these pueblos. Wells and springs were inventoried and water samples from selected wells and springs were collected and analyzed.

Dinwiddie (1963) described the occurrence of ground water near the village of Paguate, and Cooper and West (1967) summarized geohydrologic units and water use between Gallup (in McKinley County, about 60 miles northwest of Grants) and the Pueblo of Laguna. Risser and Lyford (1983) described chemical quality and availability of ground water on the Pueblo of Laguna.

Cooper and John (1968) described the geology and ground-water resources of southeastern McKinley County. This area, adjacent to northern Cibola County and within the Grants uranium region, has had a rapid increase in ground-water use.

Hiss (1975) evaluated five areas in McKinley and Cibola Counties to determine if ground water of suitable quality was available in quantities sufficient to supply the future demands of the city of Gallup. Akers (1964) described geology and ground water in central Apache County, Arizona. This area is adjacent to the western part of Cibola County.

Zuni tribal lands extend into the northwestern corner of Cibola County. As at the Pueblos of Acoma and Laguna, population growth and per capita increases in water use have required studies to locate and describe additional water resources. The first of these studies (Summers, 1972) included a well and spring inventory, aquifer tests of selected wells, reconnaissance mapping of the surficial geology, and recommendations to plan data collection, research, and water-supply development. Orr (1987) completed additional well and spring inventories on Zuni tribal lands, compiled a detailed geohydrologic map, and proposed sites for well completions.

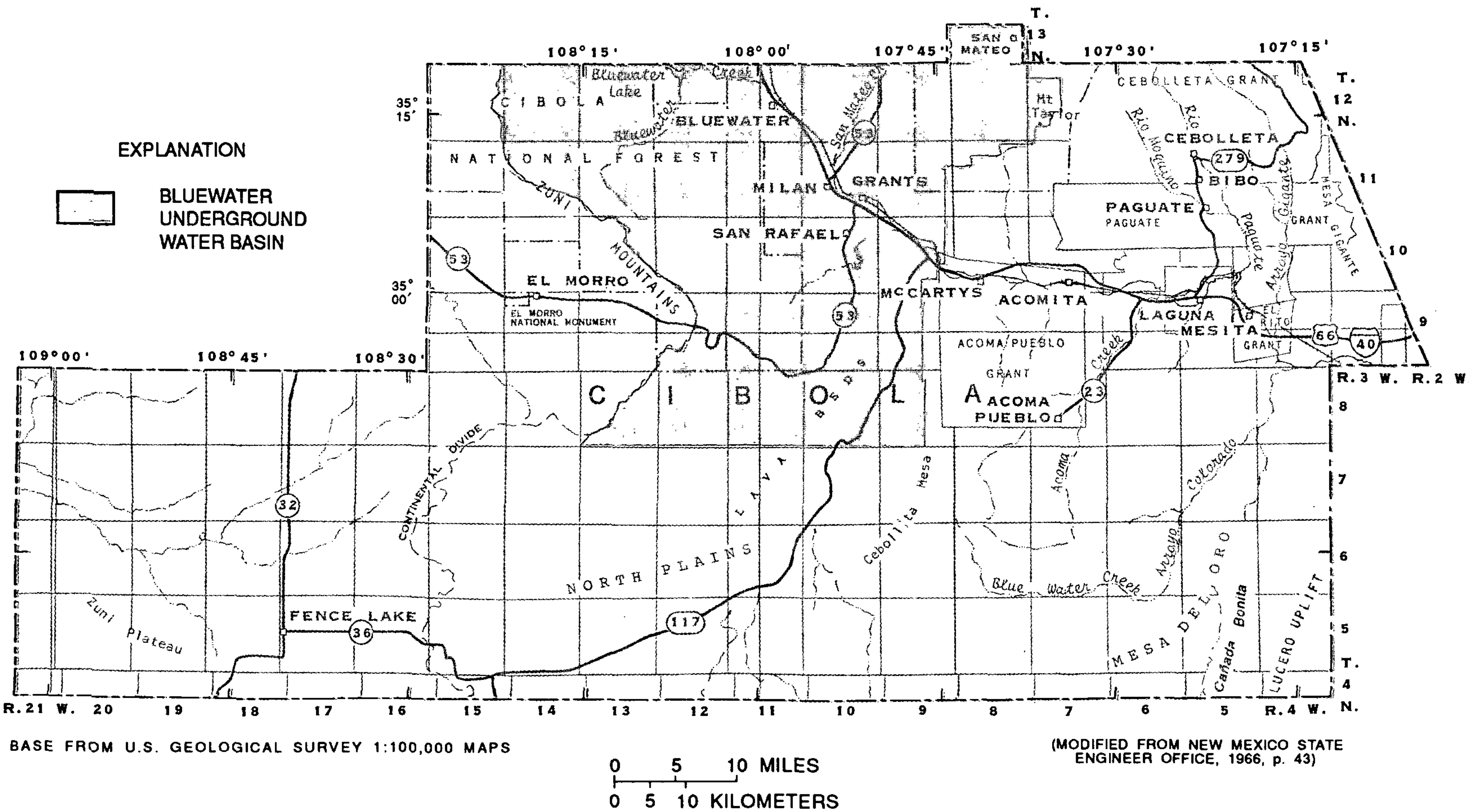


Figure 4.--Bluewater underground water basin, Cibola County, New Mexico.

West (1972) described the design and operational characteristics of an injection well in the Grants area. The well was constructed to inject uranium-mill effluent (tailing water) into deeply buried sandstone beds of the Yeso Formation of Permian age. Testing was done prior to injection, and operational data were collected to determine aquifer characteristics.

Brod and Stone (1981) described ground-water occurrence and water-quality characteristics of water in the Ambrosia Lake-San Mateo area. This area is in the Grants uranium region and includes part of north-central Cibola County. Stone and others (1983) described the geology, hydrology, and water-quality characteristics of pre-Triassic strata in the San Juan Basin. Included in their study is the area in Cibola County northeast of Interstate 40.

Acknowledgments

The authors gratefully acknowledge the many property owners of Cibola County who granted access to wells and springs and provided well and spring data. The study could not have been completed without their cooperation. Mr. Brian Easterday, Santa Fe Mining, Inc., provided coal-test-hole information from the Fence Lake area. Mr. J.H. Olsen, Jr., Sohio Western Mining Company, furnished well locations, depth to water, and well-completion data for the Sohio Western Mining L-Bar well field. Mr. Gary D. Stricker and Mr. William J. Mapel, U.S. Geological Survey, Geologic Division, provided geologic information for the western part of the county. Mr. Steven A. Smith, Salt River Project, Phoenix, Arizona, provided water-level information for wells in the southwestern part of the county.

GEOLOGY

The geologic history of Cibola County is provided by Foster (1971). Rocks of Precambrian age in Cibola County are mostly granite, with some schist, metarhyolite, gneiss, and quartzite. These rocks are exposed in the center of the Zuni Uplift. The absence of rocks from late Precambrian to Middle Pennsylvanian age in Cibola County suggests that the region was a stable early Paleozoic highland where sediments were not deposited. Major uplifts occurred during Ordovician, Devonian, and Early and Late Pennsylvanian age in the Zuni Mountains. The first rocks to be deposited after the Precambrian were limestones and conglomerates of Late Pennsylvanian age. In Early Permian time, a shallow sea extended to the area of what is now El Morro, depositing the Yeso and Abo Formations. The final advance of the Early Permian sea reached just north of the Zuni Mountains, depositing the Glorieta Sandstone and San Andres Limestone.

From the beginning of Triassic to middle Cretaceous time, west-central New Mexico generally was above sea level. The area was a low plain, and sediments from the south spread out over the partly eroded San Andres Limestone. During brief intervals a shallow brackish sea covered the area, leaving thin beds of limestone and gypsum.

During Late Cretaceous time, the seas advanced and retreated several times across the area of present-day Cibola County, creating a transgressive-regressive sequence of the Dakota Sandstone, Mancos Shale, and Mesaverde Group. Extensive coal deposits were formed during this period. Near the end of Cretaceous time the seas retreated from this area for the last time.

During the last part of the Cretaceous Period, deformation associated with the Laramide Orogeny began to form most of the existing structures in Cibola County and adjacent areas. The broad dome of the present Zuni Mountains and the Lucero Uplift began to form. Erosion began to remove sediments that had previously accumulated during Early and middle Cretaceous time. Approximately 5,000 feet of sediments were eventually removed from the eastern half of the county. The valley of the Rio San Jose was probably formed during the last part of the Cretaceous Period.

By middle Tertiary time, widespread volcanism had occurred along the southern margin of the county, and the Little Colorado River drainage system had become established on the western side of the county. The headwaters of this drainage may have extended eastward into the central part of the county.

Toward the end of Tertiary time, about 5 million years ago, the northeastern and central parts of the county became the site of extensive volcanism. This volcanism continued intermittently until as recently as 1,000 to 400 years ago. Basalt-capped mesas (pl. 1) are remnants of what was once a large basalt-covered plateau that extended over many hundreds of square miles in the central and eastern parts of the county. When the Rio Grande became established as a major drainage system about 3 million years ago, headward erosion began to extend into the county from the east.

Between about 2.5 million years and 500,000 years ago, downcutting in the vicinity of Mount Taylor removed large quantities of sediments, leaving isolated mesas, some capped with basalt. The valley of the Rio San Jose probably was formed during the last part of the Cretaceous Period. Extensive deposits that accumulated from springs discharging along the Lucero Uplift indicate that a wet climate prevailed about 2 million years ago. Alluvial deposits, which now cover many of the rocks in the county, are 200 to 300 feet thick in some valleys.

Structure

Structural features in the Cibola County area include the Zuni Uplift, Gallup Embayment, Acoma Embayment, Puerco fault zone, Lucero Uplift, and Mogollon Slope (fig. 5). The Zuni Uplift is an elongate dome about 75 miles long and 40 miles wide, and is oriented in a northwest to southeast direction. Dips on the southwestern flank are from 5 to 20 degrees and on the northeastern flank from 3 to 10 degrees. Precambrian granite and metamorphic rocks crop out in several large areas along the crest of the uplift. Normal faults are common throughout the uplift, and many of the faults are en echelon. The total displacement along the faults is usually a few tens of feet, but displacement along a fault passing beneath Grants ranges from 800 to 1,200 feet (Thaden and others, 1967).

The Gallup Embayment is west of the Zuni Uplift and is about 70 miles long from north to south. The embayment has a relatively flat bottom that is deepest on the eastern side and plunges to the north at about 60 feet per mile. Very little faulting has occurred in the embayment. The Ojo Caliente Monocline is south of the embayment. Structural relief across the monocline is about 1,200 feet.

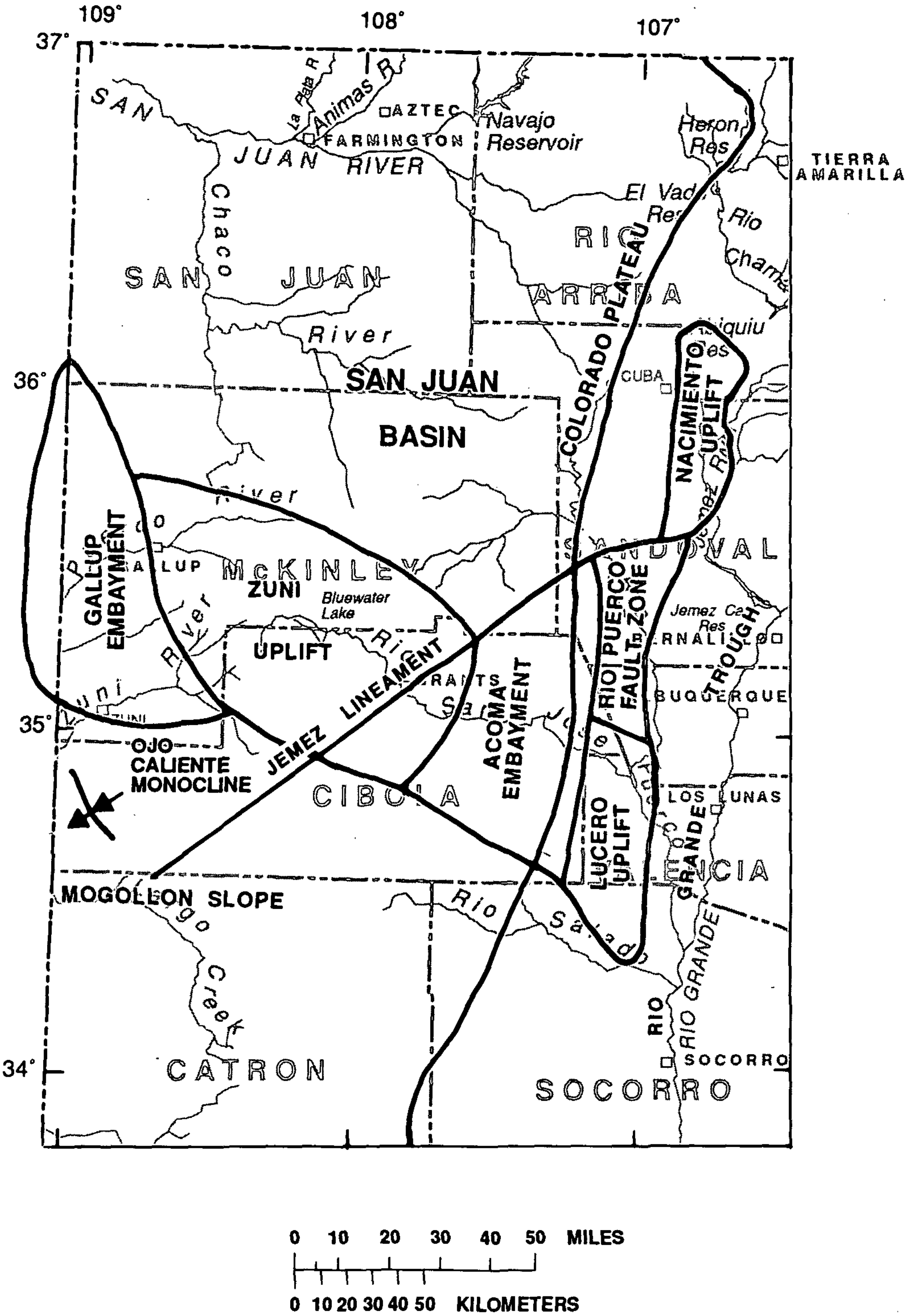


Figure 5.--Structural features of Cibola County and adjacent areas, New Mexico (modified from Fitzsimmons, 1959, fig. 1; and Laughlin and others, 1982, fig. 1).

Stratigraphy

A generalized stratigraphic section that describes the physical and water-yielding characteristics of the geologic formations is presented in table 1 (tables are in the back of the report). Much of the information in table 1 is from Gordon (1961). The stratigraphic relation of the various geologic units is illustrated on plate 1. Data on the location, owner, depth, casing diameter, completion date, water use, water level, and altitude of 244 wells and springs throughout Cibola County are presented in table 2. Water-quality analyses for 210 wells and springs are presented in table 3.

Precambrian Rocks

Igneous and metamorphic rocks of Precambrian age are exposed in the Zuni Mountains in northwestern Cibola County (pl. 1). These rocks consist of granite, gneiss, metarhyolite, schist, and quartzite. Away from the axis of the Zuni Uplift, Precambrian rocks are overlain by as much as 6,000 feet of younger strata. Generalized structure contours showing the top of the Precambrian are mapped in figure 6. Altitude data for this map are from Foster (1957, fig. 3), outcrops, and oil-test holes.

The Acoma Embayment is a broad synclinal area with a north to south orientation between the Lucero and the Zuni Uplifts. The embayment grades into the San Juan Basin to the north and into the Mogollon Slope to the south. It is marked by volcanic features such as Mount Taylor in the north and smaller volcanic centers southeast of Grants.

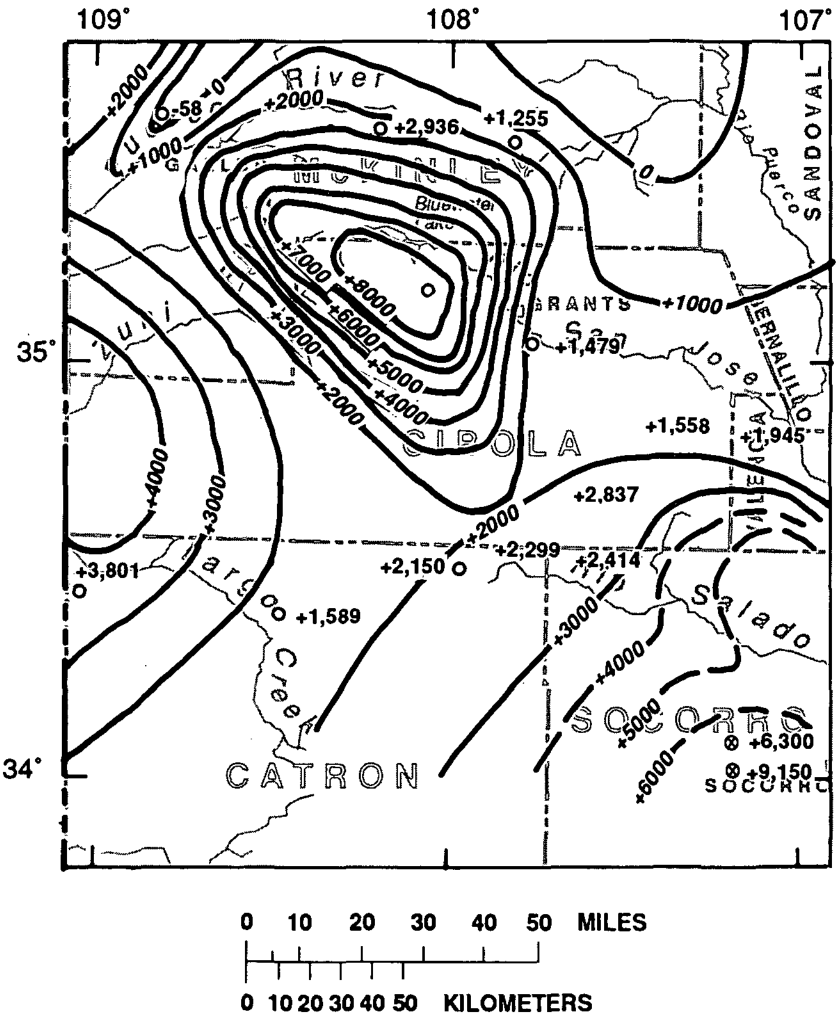
Structural features on the eastern side of the county include the Puerco fault zone and the Lucero Uplift. The Puerco fault zone, which is north of the Lucero Uplift and east of the Acoma Embayment, is a transitional zone between the Colorado Plateau to the west and the Rio Grande Trough to the east. This zone is an area of adjustment resulting from the eastward-tilted Nacimiento Uplift north of the Puerco fault zone and the westward-tilted Lucero Uplift. The zone is marked by north-trending normal faults that have downthrown sides on the west. Displacements on the faults generally are small, but a few are as much as 2,000 feet.

The Lucero Uplift borders the eastern part of the Acoma Embayment and separates it from the Rio Grande Trough. The uplift is about 40 miles long, about 10 miles wide, and may have as much as 20,000 feet of structural relief on the east side (Fitzsimmons, 1959, p. 114). The strata dip to the west on the west side of the uplift.

The Mogollon Slope structural unit is in the southwestern part of Cibola County. This area forms the southern part of the Colorado Plateau; strata generally dip to the south. Thick accumulations of volcanic rocks overlie the eastern part of the Mogollon Slope in Cibola County, obscuring older sedimentary rocks.

Pennsylvanian Rocks

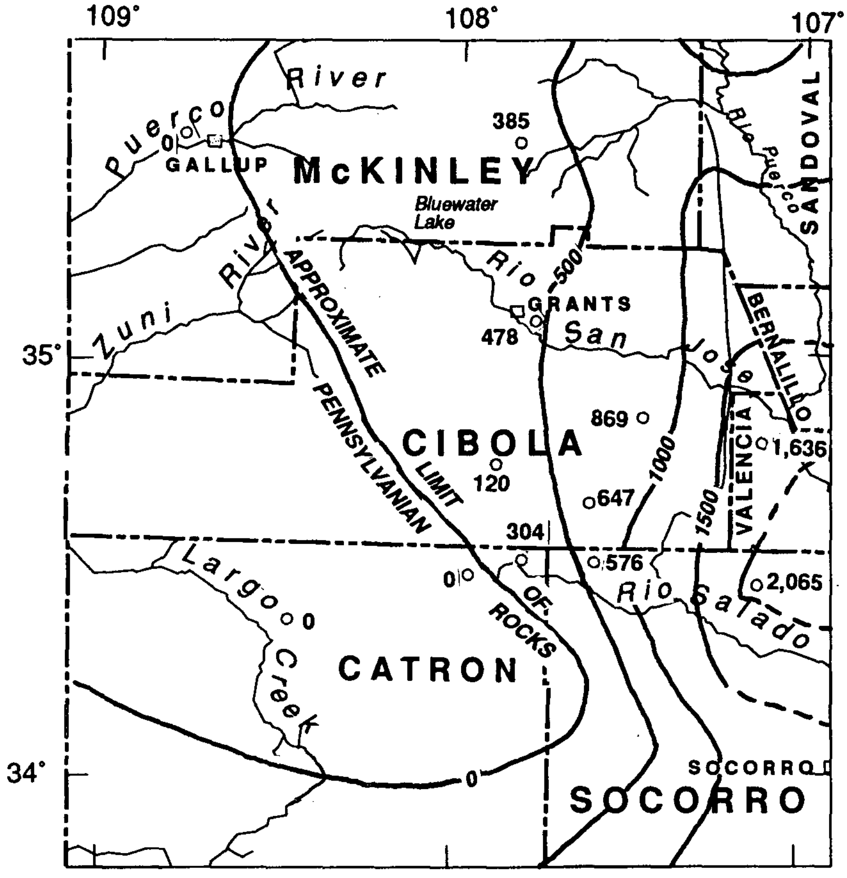
Rocks of Pennsylvanian age, composed of conglomerate, arkose, shale, and limestone, overlie Precambrian basement rock in the eastern part of the county. Information from oil-test holes and outcrops indicates that Pennsylvanian rocks wedge out on the southeastern flanks of the Zuni Mountains and attain a maximum thickness of about 2,000 feet along the eastern side of the county. Pennsylvanian rocks are not present in the western third of the county (fig. 7). Pennsylvanian rocks crop out along the extreme southeastern corner of the county and also in the Zuni Mountains. Because of the limited areal extent of Pennsylvanian outcrops in the Zuni Mountains, these rocks have been included with the overlying Abo Formation on plate 1.



EXPLANATION

—+2000—	BEDROCK CONTOUR--Shows altitude of top of Precambrian rocks. Dashed where approximately located. Contour interval 1,000 feet. Datum is sea level
o +1,589	OIL-TEST HOLE PENETRATING TOP OF PRECAMBRIAN STRATA--Number is altitude of top of Precambrian rocks above (+) or below (-) sea level, in feet
⊗ +9,150	LOCATION OF WELL SITE ON PRECAMBRIAN OUTCROP--Number is altitude of top of Precambrian rocks above sea level, in feet

Figure 6.--Generalized structure contours showing the top of Precambrian strata in Cibola County and adjacent areas, New Mexico (modified from Foster, 1957, fig 3).



0 10 20 30 40 50 MILES

0 10 20 30 40 50 KILOMETERS

EXPLANATION

500 — LINE OF EQUAL THICKNESS OF PENNSYLVANIAN STRATA--Dashed where inferred. Contour interval 500 feet

o 385 — OIL-TEST HOLE--Number is thickness of Pennsylvanian strata, in feet

Figure 7.--Thickness of Pennsylvanian strata in Cibola County and adjacent areas, New Mexico (modified from Foster, 1957, fig. 3).

Permian Rocks

Permian strata in Cibola County are (oldest to youngest) the Abo and Yeso Formations, the Glorieta Sandstone, and the San Andres Limestone. These rocks are exposed in the Zuni Mountains and along the Lucero Uplift. The thickness of Permian rocks underlying Cibola County in the Grants-Bluewater area ranges from 1,500 to 2,000 feet. Permian rocks are absent in the central part of the Zuni Uplift.

Abo Formation

The Abo Formation (Early Permian) is composed of reddish-brown sandstone, siltstone, and some conglomerate, with regular bedding and some fossils. Mud cracks, current ripple marks, and plant impressions indicate that the Abo Formation was deposited under fluvial and near-marine conditions. A thickness of 780 feet was measured in the Zuni Mountains. Oil-test holes penetrated thicknesses of 300 feet in the southwestern part of the county and 1,200 feet along the eastern boundary of the county.

Yeso Formation

In Cibola County the Yeso Formation (Early Permian) is composed of the Meseta Blanca Sandstone Member and the overlying San Ysidro Member, both of marine origin. The Meseta Blanca Sandstone Member is a crossbedded, fine-grained, reddish-brown quartzose sandstone that may contain a few feet of siltstone in the basal part. The San Ysidro Member is an evenly bedded, clayey sandstone and siltstone, similar to the underlying Meseta Blanca Sandstone Member. In the southeastern part of the county the San Ysidro Member is composed of light-colored gypsiferous shales with some grayish-white and pink sandstone. Some thin-bedded limestones may be present in the lower part.

The Yeso Formation underlies all of Cibola County with the exception of an area in the Zuni Uplift and an area in the extreme southeastern corner of the county (pl. 1). The Yeso Formation ranges in thickness from about 800 feet in the Grants-Bluewater area to about 1,400 feet on the eastern side of the county. In oil-test hole 08.04.17.000, 1,280 feet of Yeso Formation was reported.

Glorieta Sandstone

The Glorieta Sandstone is present in most of Cibola County except along the western flank of the Lucero Uplift and in the Zuni Mountains area (see figs. 5 and 19). Callender and Zilinski (1976) have identified the Glorieta Sandstone along the northeastern edge of the Lucero Uplift in Sandoval County. The Glorieta Sandstone conformably overlies the Yeso Formation. The contact between the two units is gradational and sometimes difficult to determine. In the Grants-Bluewater area, the Glorieta Sandstone consists of about 86 to 300 feet of massive, well-sorted, fine- to medium-grained sandstone. The basal part of the unit may contain some silty beds, and calcareous or silica cement is present throughout. In the southeastern part of the county, the Glorieta Sandstone consists of 135 to 200 feet of buff, well-sorted quartzose sandstone (Jicha, 1958, p. 14).

According to Baars (1962, p. 195), the Glorieta Sandstone of central New Mexico and the Coconino Sandstone of northern Arizona are identical in lithologic character, source area, and stratigraphic position, differing only in the mode of deposition. The Coconino Sandstone was deposited under eolian conditions in Arizona, whereas the Glorieta Sandstone represents marginal marine deposits in New Mexico. The source area for the Coconino and Glorieta Sandstones is postulated to have been a Precambrian quartzite upland area in central Arizona (McKee, 1933). Baars (1962, p. 200, fig. 17) showed the Glorieta Sandstone thinning gradually from about 300 feet in the southwestern part of the county to about 100 feet in the northeastern corner of the county.

San Andres Limestone

The San Andres Limestone conformably overlies the Glorieta Sandstone. Some places have extensive intertonguing of the San Andres Limestone with the Glorieta Sandstone. In the Grants-Bluewater area, the San Andres ranges from 80 to 150 feet in thickness. The unit thickens toward the southeastern part of the county where a sequence of evaporite deposits is present in the lower part of the formation (Baars, 1962, p. 208).

The San Andres Limestone varies in lithology throughout the county. Gordon (1961, p. 27) described three units in the Grants-Bluewater area: a lower massive limestone that may contain interbedded sandstone and limestone, a middle medium-grained sandstone, and an upper massive fossiliferous limestone. Jicha (1958, p. 15) divided the formation into two members in the southern part of the Lucero Uplift. A lower evaporite member, 300 to 325 feet thick, consists of thick beds of gypsum, shale, limestone, and sandstone. An upper limestone member, 100 to 125 feet thick, consists of thin to massive-bedded gray limestone.

A period of erosion at the Permian-Triassic contact exposed the San Andres Limestone to extensive solution action and erosion in the Grants-Bluewater area, resulting in the development of karst topography. Basal Chinle Formation sediments were deposited on this surface, and caverns and sinkholes were filled with Triassic sediments. The solution channels and cavernous zones generally are well connected. Orr (1987, p. 4) reported areas of karst development in the San Andres Limestone on the Zuni Indian Reservation, which is adjacent to the northwestern part of Cibola County near the Arizona border. A cavern was penetrated at the top of the San Andres Limestone during drilling at site 72 (see fig. 16), and a cavernous zone was reported in the San Andres Limestone at oil-test hole 04.11.27.000 just south of the county line. Tonking (1957, p. 12) reported the occurrence of karst features at the Chinle Formation/San Andres Limestone contact near the southern boundary of the Lucero Uplift (fig. 5).

Outcrops of the San Andres Limestone are present in the Zuni Mountains and along the Lucero Uplift. Uplift along the Ojo Caliente Monocline (fig. 5) has brought the San Andres Limestone to the surface. Elsewhere, the depth to the top of the San Andres Limestone is about 3,140 feet at site 70 (see fig. 16).

Triassic Rocks

Triassic rocks in Cibola County include the Chinle Formation and the overlying Wingate Sandstone. The Chinle Formation as described in this report includes rocks of the underlying Moenkopi Formation. The Moenkopi strata are lithologically and hydrologically similar to the overlying Chinle strata. Rocks of the Chinle Formation are present throughout most of Cibola County. The formation is absent in the area of the Zuni Mountains and along the Lucero Uplift (see figs. 5 and 20). The Chinle unconformably overlies the San Andres Limestone throughout the county. The erosional period represented by the unconformity lasted from middle Permian to Middle or Late Triassic time. Longer erosional periods occurred progressively eastward across the county (Cooley, 1959, p. 66).

Thickness of the Chinle Formation (including the Moenkopi Formation) varies considerably across the county. A thickness of 360 feet is present at well 12.10.8.314 (West, 1972, p. D6). In this area, the upper 1,000 to 1,200 feet of Chinle strata have been removed by erosion. The thickest section of Chinle Formation, about 2,080 feet, was penetrated at oil-test hole 06.11.14.000. In the southwestern corner of the county, 1,046 feet of Chinle was present at site 62 (see fig. 16).

The Chinle Formation in Cibola County consists of the Monitor Butte Member and the overlying Petrified Forest Member. The Monitor Butte Member, which probably is equivalent to the lower member of the Chinle Formation in the Grants-Bluewater area, is composed of reddish-brown siltstone and mudstone interbedded with silty and conglomeratic sandstone. The Monitor Butte Member is about 300 feet thick in the western part of the county and may be as much as 200 to 350 feet thick in the Zuni Mountains area (Repenning and others, 1969, p. B20).

Thickness of the Petrified Forest Member in the county ranges from zero to 1,300 feet. The member is divided into a lower and an upper part separated by the Sonsela Sandstone Bed (Cooley, 1959, p. 70). The lower part consists of light-gray to red and brown mudstone and tuffaceous siltstone and mudstone.

The Sonsela Sandstone Bed of the Petrified Forest Member is composed of grayish-white to brownish-buff, very fine to very coarse grained sandstone and conglomeratic sandstone, with thin lenses of mudstone and siltstone throughout the unit (Cooley, 1959, p. 71). The sandstone bed is as much as 30 feet thick, but varies in thickness over short distances. The Sonsela Sandstone Bed was deposited by streams flowing from the south in the ancient Mogollon Highlands. The distribution of conglomerate in the sandstone indicates that two large streams deposited most of the Sonsela material in the western part of Cibola County (Cooley, 1959, fig. 6). An absence of conglomerate in the Sonsela beds in the southeastern part of the county (Jicha, 1958) indicates that no major northward-flowing streams were in this area.

The upper part of the Petrified Forest Member consists of brownish-red to bright-red siltstone and mudstone with abundant limestone beds in the western part of the county. Thickness of the upper part of the Petrified Forest Member is estimated to be about 1,000 feet throughout the county except where the unit is absent or partially removed by erosion.

The Correo Sandstone Bed occurs in the upper part of the Petrified Forest Member. This unit is restricted to the east-central part of the county and crops out locally in the Rio San Jose Valley. The bed is composed of as much as 100 feet of fine- to coarse-grained reddish sandstone with conglomerate lenses near the bottom and siltstone beds near the top (Moench and Schlee, 1967, p. 5). The Correo Sandstone Bed is probably a fluvial-channel deposit that has a northwesterly transport direction and a nearby source area to the southeast (Moench and Schlee, 1967, p. 6).

The Wingate Sandstone, represented in Cibola County by the Rock Point Member, resulted from continued deposition under continental conditions. At the type locality, 15 miles south of Rock Point in northeastern Arizona, the Rock Point Member is composed of about 350 feet of reddish-brown silty sandstone and siltstone deposited under fluvial conditions (Harshbarger and others, 1957, p. 9). In Cibola County, the Rock Point Member is thin and the sediments tend to be more coarse grained. In the Grants-Bluewater area, Wingate sedimentary rocks are composed of 80 to 120 feet of reddish-brown eolian sandstone. Farther east, in the Pueblo of Acoma area, the Rock Point (?) Member consists of about 260 feet of reddish-brown silty sandstone overlain by about 65 feet of thick-bedded, white, fine-grained sandstone (Maxwell, 1976, p. 95). Orr (1987, p. 5) described the Rock Point Member on Zuni tribal lands as consisting of about 150 feet of reddish-brown fluvial siltstone and fine-grained sandstone.

The Rock Point Member of the Wingate Sandstone is absent in the Zuni Uplift, in the southeastern part of the county, and in the northwestern part of the panhandle, where it has been completely eroded. In addition, the Rock Point Member is absent over a large area of the Pueblos of Acoma and Laguna.

Jurassic Rocks

Jurassic rocks, which include the San Rafael Group and the Zuni and Morrison Formations, unconformably overlie Triassic rocks. Erosion has removed Jurassic sediments from areas of the Lucero and Zuni Uplifts, from the southern part of the county, and from an area northeast of the Ojo Caliente Monocline. The areas where Jurassic strata remain are shown in figure 8. The greatest thickness of Jurassic rocks, about 1,100 feet, is in the northeastern part of the county. The San Rafael Group includes, from oldest to youngest, the Entrada Sandstone, Todilto Limestone, Summerville Formation, and Bluff Sandstone (Foster, 1957 and 1971; Gordon, 1961). The Zuni Sandstone is a lateral equivalent of the Bluff, but is not part of the San Rafael Group. The following summary of the San Rafael Group, Zuni Sandstone, and Morrison Formation is taken from Harshbarger and others (1957), Gordon (1961), Moench and Schlee (1967), and Maxwell (1976).

Entrada Sandstone

The Entrada Sandstone consists of an upper and lower sandstone facies that may be separated by a middle siltstone unit. The upper and lower sandstones are reddish brown, fine to coarse grained, and generally are well cemented. Where present, the middle siltstone unit also is reddish brown and may contain some thin-bedded, very fine grained sandstone. The lower sandstone unconformably overlies the Wingate Sandstone where present and the Chinle Formation, and in the Laguna area fills channels that have cut into the Chinle. The sandstones become coarse grained toward the south. The Entrada Sandstone is about 270 feet thick in northeastern Cibola County and is truncated in the southern part of T. 6 N., in the southeastern part of the county. In the northwestern part of the county, the Entrada Sandstone is about 350 feet thick. The sandstone thins rapidly to the south and pinches out in the southern part of T. 7 N.

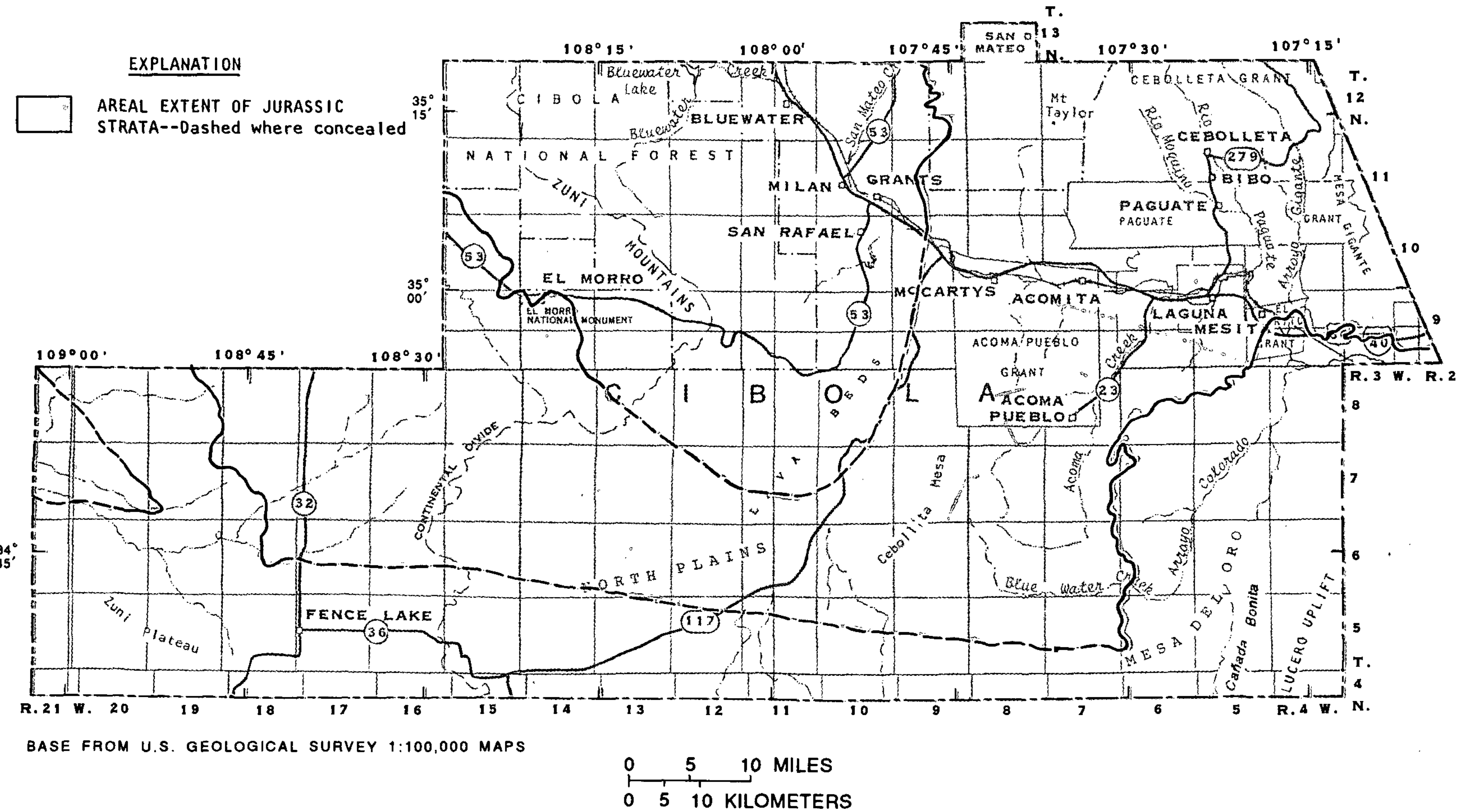


Figure 8.--Extent of Jurassic strata in Cibola County, New Mexico.

Todilto Limestone

The Todilto Limestone is composed of a light-, to dark-gray, thin-bedded limestone, overlain by a thick but less extensive gypsum-anhydrite unit. The limestone is thin but extensive: it has a thickness of 36 feet in the Paguate area, 30 feet in the Grants-Bluewater area, and about 10 feet in the Acoma Pueblo area. The gypsum-anhydrite unit is about 74 feet thick in the vicinity of Paguate. The unit is truncated just south of the Pueblo of Acoma and is absent in the western half of the county.

Summerville Formation

The Summerville Formation consists of reddish-brown, fine-grained sandstone and silty mudstone. The mudstones predominate in the lower part of the formation whereas sandstones are more common in the upper part. The formation becomes more coarse grained toward the south where the source area probably was located. The formation is about 185 feet thick in the Paguate area, about 200 feet thick in the Grants-Bluewater area, and dips toward the north into the San Juan Basin. The Summerville Formation extends south beyond the Entrada pinch-out in the eastern part of the county and unconformably overlies the Chinle Formation. The formation is truncated by the basal Dakota unconformity along the southern border of Cibola County. This truncation marks the southernmost Jurassic strata in the county. The Summerville Formation is absent in the western half of the county. Because of the thickness and fine-grained nature of the Summerville strata, the formation is considered to be a confining unit that separates the Todilto-Entrada aquifer from the overlying Dakota-Zuni-Bluff aquifer.

Bluff Sandstone and Zuni Sandstone

The Bluff Sandstone and the laterally equivalent Zuni Sandstone are composed of light-gray to light-brown, fine- to medium-grained, massive, well-sorted, crossbedded sandstone. The Bluff Sandstone intertongues with the underlying Summerville Formation and the overlying Morrison Formation throughout Cibola County. The Bluff Sandstone also intertongues laterally with the Zuni Sandstone. In the northern part of the Acoma area the Bluff Sandstone is about 230 feet thick, whereas toward the south, the Zuni and the Bluff Sandstones have a combined thickness of about 900 feet. In the Paguate area, the Bluff Sandstone ranges from 200 to 400 feet in thickness and averages about 300 feet in thickness. The Bluff Sandstone is about 200 feet thick in the Grants-Bluewater area; it is not present in northwestern Cibola County, where it is laterally replaced by the Zuni Sandstone, which is about 500 feet thick (Orr, 1987, p. 5). The lower part of the Bluff Sandstone is believed to have been deposited under fluvial conditions, whereas the upper part is eolian in nature. The Zuni Sandstone is eolian throughout and also intertongues with the Summerville and Morrison Formations. The Zuni Sandstone probably was deposited on the southern margin of the Jurassic basin and marks the advance and retreat of eolian facies as the Jurassic seas advanced and retreated. The upper part of the Zuni Sandstone is truncated by the unconformity at the base of the Dakota Sandstone. In the eastern part of the county the truncation is in the middle of T. 6 N., and in the western part of the county the southernmost occurrence of Zuni Sandstone is along the southern part of T. 7 N. In the eastern part of the county the Zuni and Bluff Sandstones dip toward the north into the San Juan Basin. In the western part of the county the Zuni Sandstone dips southwest away from the Zuni Uplift (Orr, 1987, p. 7).

Morrison Formation

Four members of the Morrison Formation are present in the study area: they are, from oldest to youngest, the Recapture Member, Westwater Canyon Member, Brushy Basin Member, and Jackpile Sandstone Member. The members of the Morrison Formation were deposited by a system of braided streams on the underlying Zuni Sandstone and San Rafael Group (Harshbarger and others, 1957, p. 55). The source area for the three members was to the south in the ancient Mogollon Highlands.

The Recapture Member consists of reddish-brown claystone and siltstone with some light-gray, poorly sorted, very fine grained sandstone. Claystone and siltstone are common in the lower part of the member, whereas sandstone predominates in the upper part. The member is about 100 feet thick in the Paguate area and ranges from 75 to 200 feet thick in the Grants-Bluewater area. The Recapture Member thins toward the south in the eastern part of the county and is absent south of the Rio San Jose. The member is absent in the western half of the county. Because of the presumed small hydraulic conductivity of the rocks, the Recapture is believed to function as a confining bed between the underlying Zuni and Bluff Sandstones and the overlying Westwater Canyon Member.

The Westwater Canyon Member of the Morrison Formation consists of very fine to coarse-grained, massive, crossbedded sandstone. The member is about 110 feet thick in the Grants-Bluewater area, as much as 90 feet thick in the Paguate area, and about 120 feet thick in the western part of the county. The member thins southward across the county because of erosion along the pre-Dakota unconformity. In the eastern part of the county, the Westwater Canyon Member is absent south of the Rio San Jose. In the western panhandle of the county, the member is truncated north of the county line. Uranium ore has been discovered in large areas of the Westwater Canyon Member in northeastern Cibola County and southwestern McKinley County.

The Brushy Basin Member is composed of greenish-gray mudstone and some silty and sandy zones. In some areas the mudstone is a bentonitic clay. A basal conglomerate usually is present in the Brushy Basin Member. The member locally may contain large quantities of sandstone similar in lithology to the Westwater Canyon Member (Moench and Schlee, 1967, p. 19). The Brushy Basin Member is 220 to 300 feet thick in the Paguate area and 150 to 200 feet thick in the Grants-Bluewater area. It thins toward the west and has a thickness of about 50 feet near Bluewater. In the eastern part of the county the member is absent south of the Rio San Jose due to pre-Dakota erosion.

The Jackpile Sandstone Member overlies the Brushy Basin Member. This white, fine- to medium-grained sandstone is as much as 200 feet thick in the Paguate area and occurs in the northeastern part of the county as a narrow beltlike deposit with a northeasterly trend. The sandstone contains uranium deposits and has been extensively mined (Owen and others, 1984).

Cretaceous Rocks

Deposition of Jurassic strata was followed by a long erosional period during Early Cretaceous time when much of the Jurassic section was eroded. Cretaceous seas then invaded the area and deposited shoreline deposits of the Dakota Sandstone and offshore marine deposits of the Mancos Shale. Regressive and transgressive cycles of the Cretaceous seas created extensive intertonguing of the Mancos Shale and the overlying Mesaverde Group. Total thickness of Cretaceous rocks originally deposited in the county is estimated to have been at least 5,000 feet (Moench and Schlee, 1967, p. 2).

Dakota Sandstone

The Dakota Sandstone crops out in the northeastern part of the county and on the southwestern flanks of the Zuni Mountains. The unit is absent in the southeastern part of the county, in the area of the Zuni Uplift, and in an area northeast of the Ojo Caliente Monocline.

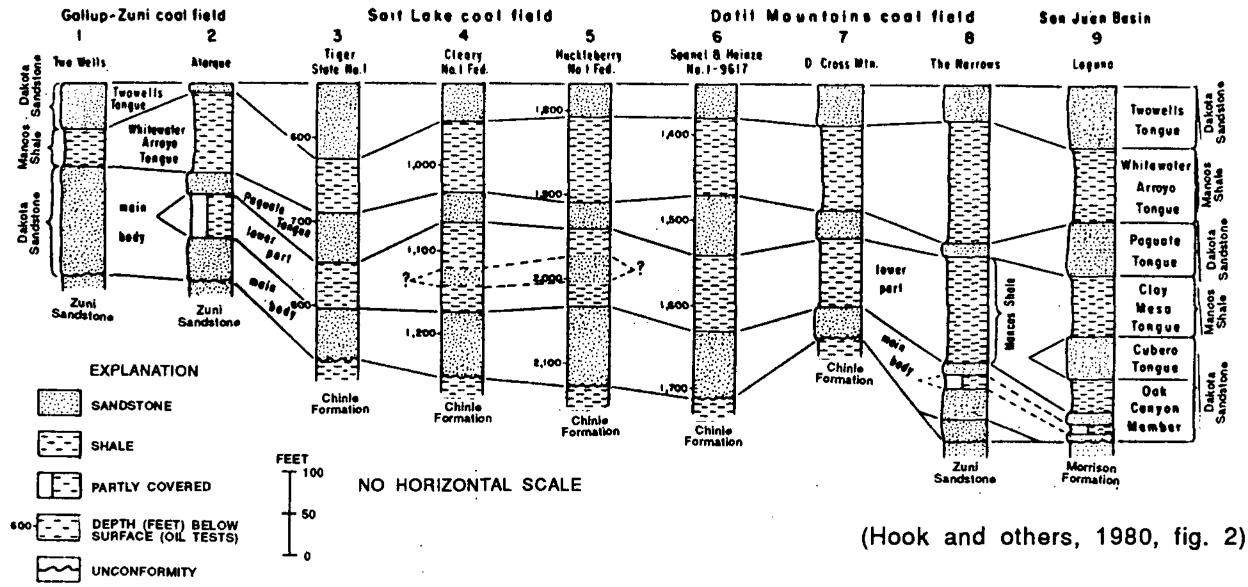
The Dakota Sandstone consists of a series of sandstone units separated by tongues of the Mancos Shale. In the eastern part of the county the four sandstone tongues in the Dakota, from oldest to youngest, are the Oak Canyon Member, Cubero Tongue, Paguate Tongue, and Twowells Tongue (Owen and Siemers, 1977). The total thickness of the sandstone tongues and the intervening shale beds ranges from about 200 to 530 feet; sandstones account for 90 to 310 feet of the total thickness. Anderson (1982c) has identified three sandstone units of the Dakota Sandstone in the western part of the county: the main body of the Dakota Sandstone, the Paguate Tongue, and the Twowells Tongue. The combined thickness of these sandstone and shale tongues is about 220 feet; sandstone beds account for about 140 feet of this total. The Paguate Tongue merges with the main body of the Dakota Sandstone about 12 miles west of Grants, and the Cubero Tongue of the Dakota Sandstone wedges out in the western part of the Acoma area (Hook and others, 1980, p. 42). Tongues of the Mancos Shale that separate tongues of the Dakota Sandstone generally are 50 to 100 feet thick. The Whitewater Arroyo Tongue of the Mancos Shale, however, is as much as 150 feet thick in the vicinity of T. 4 N., R. 10 W., secs. 3 and 4. The correlation between the various tongues of the Dakota Sandstone in the eastern and western parts of the county and the thickness of the sandstone and shale tongues at various locations are shown in figure 9; also shown is the unconformable relation between the Dakota Sandstone and the underlying Jurassic strata in the eastern and western parts of the county.

The Dakota Sandstone consists of yellowish-orange to light-brown, fine- to medium-grained, silty sandstone. Sandstones in the lower part of the Dakota Sandstone tend to be more coarse grained and poorly sorted and to contain less silt-sized material than do upper sandstones, such as the Twowells Tongue. The main body of the Dakota Sandstone (the Oak Canyon Member in the eastern part of the county) and the Twowells Tongue are regionally continuous across the county, except where removed by erosion.

Mancos Shale

The Mancos Shale extensively intertongues with the underlying Dakota Sandstone and the overlying Mesaverde Group. The basal part of the Mancos Shale also intertongues with the Tres Hermanas Sandstone Member (Hook and others, 1983). The stratigraphic correlation of the tongues of the lower Mancos with the tongues of the Dakota Sandstone is shown in figure 9. Overlying the Twowells Tongue of the Dakota Sandstone is a thick section of Mancos Shale referred to in this report as the main body of the Mancos Shale (Maxwell, 1976, p. 100). Hook and others (1983) referred to this tongue as the Rio Salado Tongue of the Mancos Shale.

The main body of the Mancos is a dark-gray calcareous marine shale with some silty and sandy zones. This unit forms weathered slopes and lowlands throughout the county (pl. 1). The main body is 330 to 385 feet thick in the vicinity of the Pueblo of Acoma and is 225 to 240 feet thick north of Fence Lake. Because of its great thickness and small hydraulic conductivity, this shale unit is considered to function as an effective confining unit, separating the Dakota-Zuni-Bluff aquifer from aquifers in the overlying Mesaverde Group. No wells are known to be completed in the main body of the Mancos Shale.



(Hook and others, 1980, fig. 2)

Location of sections shown above

1.--Two Wells--outcrop section from Dane and others (1971, p. 318); measured in NE 1/4 sec. 17, T. 12 N., R. 19 W., McKinley County, New Mexico

2.--Atarque--outcrop section measured by C.H. Dane, E.R. Landis, and W.A. Cobban in sec. 24, T. 6 N., R. 18 W., Valencia County, New Mexico

3.--Tiger State No. 1--oil test drilled in sec. 8, T. 4 N., R. 17 W., Valencia County, New Mexico

4.--Cleary No. 1 Federal--oil test drilled in sec. 6, T. 3 N., R. 16 W., Catron County, New Mexico

5.--Huckleberry No. 1 Federal--oil test drilled in sec. 11, T. 2 N., R. 16 W., Catron County, New Mexico

6.--Spanel and Heinze No. 1-9617--oil test drilled in sec. 27, T. 4 N., R. 11 W., Catron County, New Mexico

7.--D Cross Mountain--outcrop section measured by B. Robinson in secs. 8, 21, T. 3 N., R. 8 W., Socorro County, New Mexico

8.--The Narrows--outcrop section from Landis and others (1973, p. J36-J37) measured in secs. 3, 4, T. 7 N., R. 10 W., Valencia County, New Mexico

9.--Laguna--outcrop section from Landis and others (1973, p. J4-J8) measured in secs. 20, 21, T. 10 N., R. 5 W., Valencia County, New Mexico

(Hook and others, 1980, table 1)

Location map for above section

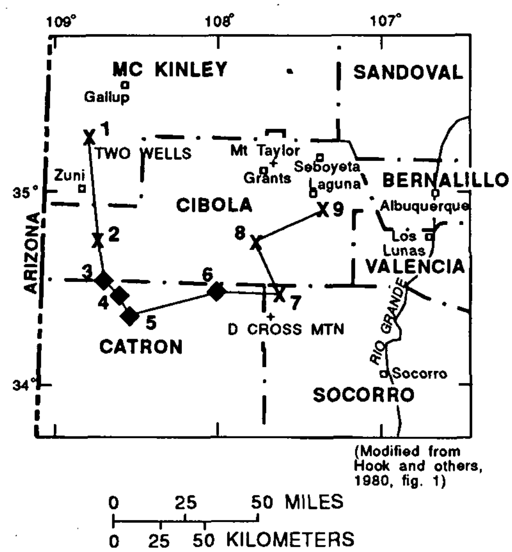


Figure 9.--Generalized section showing correlation of the intertongued Dakota Sandstone and Mancos Shale sequence in Cibola County and adjacent areas, New Mexico.

Mesaverde Group

In Cibola County the Mesaverde Group consists of the Point Lookout Sandstone and is underlain by, in ascending order, the Gallup Sandstone and Crevasse Canyon Formation (table 1). The Atarque Sandstone and Moreno Hill Formation (McLellan and others, 1982), which occur in the southwestern part of the county, are mapped with the Gallup Sandstone in this study although they are not part of the Mesaverde Group. The extent of Mesaverde Group sedimentary rocks is shown in figure 10.

The Gallup Sandstone consists of marine and nonmarine sandstones, carbonaceous mudstones, and thin coal beds. Maxwell (1976, p. 99) listed three members of the Gallup Sandstone separated by tongues of the Mancos Shale in the Pueblo of Acoma area. The sandstone beds range from about 20 to 90 feet in thickness and the intervening shale tongues range from 20 to 130 feet in thickness. The total thickness of the sandstone-shale interval in the Acoma area ranges from about 240 to 360 feet. The thickness of the Gallup Sandstone may be as much as 400 feet in the western part of the county. The Gallup Sandstone has been removed by erosion from a large area on the eastern side of the county, in the Zuni Mountains, and in the northwestern part of the county panhandle (fig. 10).

The Crevasse Canyon Formation conformably overlies the Gallup Sandstone and also intertongues with the Mancos Shale. Sediments of the Crevasse Canyon Formation are similar in lithology to the Gallup Sandstone. The Crevasse Canyon Formation consists of the Dilco Coal Member, Dalton Sandstone Member, and Gibson Coal Member. The Point Lookout Sandstone (Late Cretaceous) occurs in the northwestern part of the county, where it conformably overlies the Crevasse Canyon Formation. In the vicinity of the Pueblo of Acoma, the Crevasse Canyon Formation and the Point Lookout Sandstone are about 800 feet thick and the Mulatto Tongue of the Mancos Shale is about 300 feet thick (Maxwell, 1976, p. 99). In the western part of the county, the Crevasse Canyon Formation is only about 100 feet thick because much of the formation was removed by erosion. Crevasse Canyon strata presumably are present under parts of the North Plains area, although Maxwell (1981) has mapped isolated Dakota and Zuni Sandstone outcrops in the south-central part of Cibola County. If these outcrops of Upper Cretaceous rocks represent uplift along northwest-trending folds or faults, as Maxwell suggests, then much of the Mesaverde Group may have been removed by erosion prior to emplacement of the volcanic material now present. Much of the Crevasse Canyon Formation is present as isolated buttes and mesas throughout the county.

Tertiary Rocks

Rocks of Tertiary age in Cibola County include the Spears Formation (Chapin, 1971) and the Fence Lake Formation (formerly called the upper member of the Bidahochi Formation). Deposits of the Spears Formation of Chapin (1971) occur along the southern border of the county in Tps. 14 and 15 W. (pl. 1). The deposits are composed of interbedded claystones and volcanic wackes (Guilinger, 1982, p. 52). The thickness of the Spears Formation in Cibola County is not well known but is believed to be about 200 to 300 feet. The formation probably is unsaturated in Cibola County.

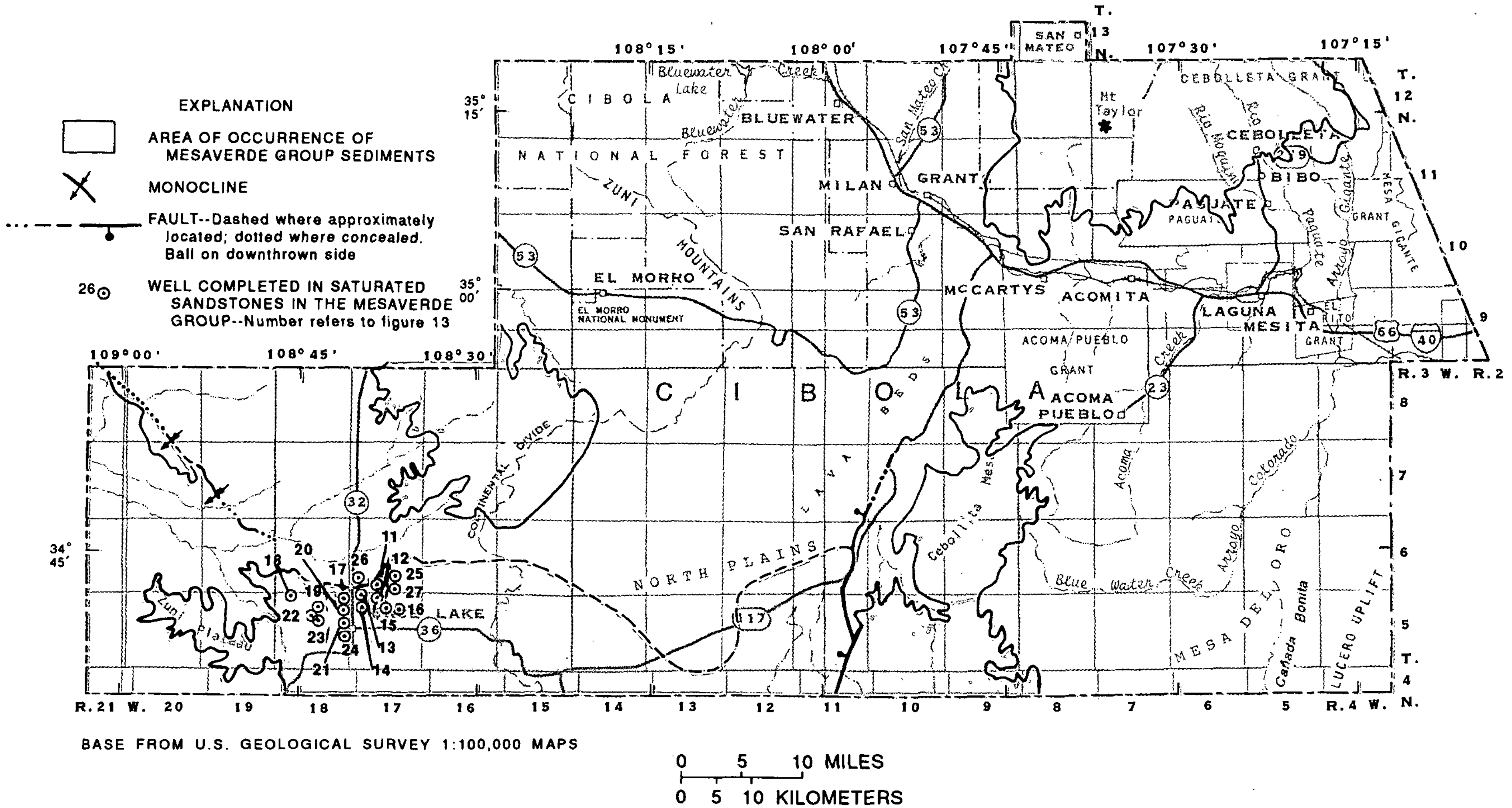


Figure 10.--Extent of Mesaverde Group in Cibola County, New Mexico.

The Fence Lake Formation, as described by McLellan and others (1982), is present only along the western side of the county and consists of as much as 200 feet of unconsolidated fluvial and lacustrine sands and gravels. This material was deposited on a pre-Tertiary erosional surface in the ancestral valley of the Little Colorado River (Cooley and others, 1969, p. A35). Drainage in this ancestral valley was from east to west, and blockage in the valley caused accumulation of Fence Lake sediments in the western part of the county and adjacent areas of Arizona. These sediments once covered large areas of western Cibola County and eastern Arizona, but erosion subsequently has removed much of the formation. On Zuni tribal lands north of the panhandle, the Fence Lake Formation is an important aquifer and may be more than 650 feet thick (Orr, 1987, p. 6). However, in Cibola County, the Fence Lake occurs as remnants capping mesas and plateaus and generally is unsaturated. No wells were found to be completed in Fence Lake sediments.

Tertiary and Quaternary Rocks

Volcanism in Cibola County has occurred along the Jemez Lineament (fig. 5), a northeast-trending shear zone of regional scale that crosses the county (Laughlin and others, 1982). At some locations along the Jemez Lineament volcanism has occurred intermittently during late Tertiary and early Quaternary times. Tertiary and Quaternary basalt flows cap mesas in the southeastern part of the county and are found on mesas northeast of Grants. Tertiary and Quaternary volcanic material also forms the Mount Taylor composite volcano. Tertiary and Quaternary intrusive dikes, sills, and plugs mainly occur in the eastern part of the county. Reports describing the occurrence, composition, and age of the basalts include those by Goddard (1966), Laughlin and others (1972), Lipman and Moench (1972), Maxwell (1981), Crumpler (1982), and Laughlin and others (1983).

Thickness of the Tertiary and Quaternary basalts varies considerably across the county. Some of the thinner flows that cap mesas are 200 to 300 feet thick, whereas on Cebollita Mesa, basalt thickness ranges from 800 to 1,000 feet. Accumulations of volcanic material at Mount Taylor may be as much as 3,000 feet thick.

The structure of the volcanic rocks in the county is highly variable. Volcanic material extruded from flow units is commonly dense to vesicular with massive flow centers and rubble or brecciated interflow zones. Individual flows are of varying thicknesses, and soil horizons or accumulations of alluvium are commonly found in the interflow zones. Volcanic material on Mount Taylor is interbedded with mudflows, volcaniclastic debris, dikes, and pyroclastic flow material.

Quaternary Deposits

Quaternary material in Cibola County includes basalt flows and alluvial deposits. Quaternary basalt is found in the central and western parts of the county, in the Zuni Mountains, and along the Rio San Jose Valley. Basalts in the central and western parts of the county were extruded from numerous vents and fissures in the central and northern part of the North Plains. Some of the basalt flowed to the northwest along the Rio Pescado drainage, whereas another finger of basalt flowed west along an old channel of the Little Colorado River. These basalt flows are shown on plate 1. Cinder cones, collapse structures, and lava tubes are volcanic features of the North Plains. From a small cinder cone in T. 7 N., R. 11 W., sec. 28, McCartys Basalt extends north to the valley of the Rio San Jose and then eastward down the valley. The age of this recent flow is estimated to be 400 to 1,000 years (Maxwell, 1981). The Bluewater basalt, which has exposures north of Grants, underlies a large part of the Grants-Bluewater area. The source of the lava was a vent located about 2 miles north of the Cibola County line, in T. 13 N., R. 10 W. Basalts from eruptive centers in the Zuni Mountains flowed down canyons to the northeast and southwest out of the mountainous area.

Thickness of the basalt on the northwestern side of the North Plains is indicated from drillers' logs. About 149 feet of lava was present at well 09.15.01.311, about 120 feet of lava at well 09.14.05.214, and 320 feet of malpais and red cinders at well 07.15.23.223. Basalt thicknesses in the central part of the North Plains may be greater than 300 feet. Cooley and Akers (1961, p. C-245) suggested that an ancestral valley of the Little Colorado River extended east across western Cibola County into the North Plains area. In prevolcanic times the Continental Divide may have been located as much as 25 miles east of its present position. The current location of the divide may have been created by accumulation of extensive thicknesses of basalt extruded along a northeast-trending fault zone described by Maxwell (1981). The trace of the ancestral Little Colorado River Valley is now expressed by the sinuous basalt flow that trends west-northwest across the panhandle of the county (pl. 1). The more resistant basalt flow now overlies Cretaceous strata that were eroded from both sides of the flow. Near Grants 197 feet of basalt was present at oil-test hole 10.09.21.223.

Quaternary alluvium forms a veneer over many of the older deposits in the county. In most places this material, which consists of unconsolidated sands, silts, and gravels, is only a few tens of feet thick and is unsaturated. In some parts of the county, such as along the Rio San Jose Valley, however, the alluvium is relatively thick and serves as a locally important source of water. The extent of alluvial material in the county is shown on plate 1. Gordon (1961, table 3) reported that alluvium in the Grants-Bluewater area can be as thick as 100 feet. Farther east, in the vicinity of Laguna, well 08.04.29.444 penetrated 287 feet of basalt and alluvium. In the southeastern part of the county extensive alluvium covers the Chinle Formation. The thickness of the alluvium in this area is 150 to 200 feet. In areas where basalt flows filled existing stream channels or valleys, fluvial deposits are often buried by the basalts. Orr (1987, p. 6) reported that as much as 150 feet of unconsolidated sand and gravel is buried by basalt in the Zuni River Valley just north of the county panhandle. Such buried channels may also be present in the El Morro area. Gordon (1961, p. 37) reported that interbedded basalt and alluvial material in the Grants-Bluewater area ranges from 100 to 140 feet thick.

Landslide and slump material of Quaternary age is found in the eastern part of the county. This material mainly is found around sandstone- or basalt-capped mesas, where erosion of the underlying, less resistant rocks has resulted in slumping and landslides of the overlying, more resistant rocks. This material probably is no more than a few tens of feet thick.

An extensive travertine deposit is located in the southeastern part of the county; this travertine deposit is about 4 miles in length and about 1 1/2 miles in width. Jicha (1958, p. 26) stated that the travertine has a maximum thickness of more than 150 feet.

HYDROLOGY

Because of the semiarid to arid climate in Cibola County, ground water is the most dependable source of water. The Rio San Jose is the only perennial stream in the county. In this report, the hydrogeologic aspect and water quality of 12 geologic units within the study area are discussed. Eight of these have been developed as sources of water and are principal aquifers throughout the county. They include Quaternary alluvium and alluvial-basalt sequences, Quaternary and Tertiary basalts, sandstones in the Mesaverde Group, the Dakota-Zuni-Bluff aquifer, the Westwater Canyon aquifer, the Todilto-Entrada aquifer, sandstones in the Chinle Formation, and the San Andres-Glorieta aquifer. For more information concerning the San Andres-Glorieta aquifer, refer to Baldwin and Anderholm (1992). Four units are not major sources of water: the Rock Point Member of the Wingate Sandstone, Yeso Formation, Abo Formation, and Precambrian rocks.

Quaternary Deposits

Numerous stock and domestic wells are completed in Quaternary alluvium and alluvial-basalt sequences throughout Cibola County (table 2; Risser and Lyford, 1983, table 1). Well depths range from 10 feet reported in well 06.17.33.212 to 473 feet in well 09.14.06.313.

Well yields from alluvial material along the Rio San Jose Valley can be large. At well 10.07.36.424a, a yield of 490 gallons per minute was recorded (Risser and Lyford, 1983, table 1), and at well 11.10.21.221, a yield of 1,110 gallons per minute was recorded (Gordon, 1961, table 4). In other areas, well yields of 5 to 10 gallons per minute are more common.

Water from alluvial material is highly variable in chemical composition, and its quality depends on the properties of the underlying rocks, the position of the well in the flow system, and whether the alluvium receives leakage from underlying units or recharge from precipitation or runoff. Dissolved-solids concentrations range from 200 to more than 5,200 milligrams per liter. In the southeastern part of the county where alluvial material is underlain by the Chinle Formation, dissolved-solids concentrations range from 650 to 3,900 milligrams per liter. The predominant ions in water include calcium and magnesium at well 06.17.33.212, sodium and sulfate at well 11.15.32.242, and calcium at well 06.11.34.113.

Quaternary and Tertiary Basalts

Saturated volcanic materials have the potential to yield large quantities of water to wells. In Cibola County much of the volcanic material that caps mesas is unsaturated. Basalt flows in valleys may or may not be saturated, depending on whether the regional water table is in or below the basalt. Gordon (1961, p. 37) noted that numerous springs that provide water for stock and domestic use issue from basalts along the margins of mesas near Grants. Risser and Lyford (1983, table 2) noted a discharge of about 100 gallons per minute from Quaternary and Tertiary basalt at Encinal Public Supply Spring (10.06.22.333). Springs in the Mount Taylor area were inventoried during summer 1981. Some of the springs were seeps or were not flowing at the time of the visit. However, these springs probably flow during the spring snowmelt period or following summer thunderstorms. The location of these springs is shown in figure 11, and information on them is listed in table 2.

Recharge to Quaternary and Tertiary basalts mainly is from precipitation. Topographic maps show that, for the most part, the basalts have no surface-water drainage systems; therefore, little recharge from streamflow can occur. In addition, there is little or no surface runoff from the basalts; precipitation either rapidly infiltrates into the permeable basalts or returns to the atmosphere by evapotranspiration. In the Mount Taylor area the volume of infiltration probably is greater than that at lower altitudes because of larger precipitation volumes and smaller evapotranspiration rates. Ground water moves downward through the Mount Taylor volcanics until it is diverted laterally by small-permeability units within the volcanic material or reaches the regional water table. In addition to small-permeability units in the volcanic material, the natural dip of volcanic strata away from the central part of the mountain may also help to divert downward-moving water laterally to discharge as springs on the flanks of the mountain. Spring discharge from the Quaternary and Tertiary basalts ranges from a seep to as much as 2 gallons per minute.

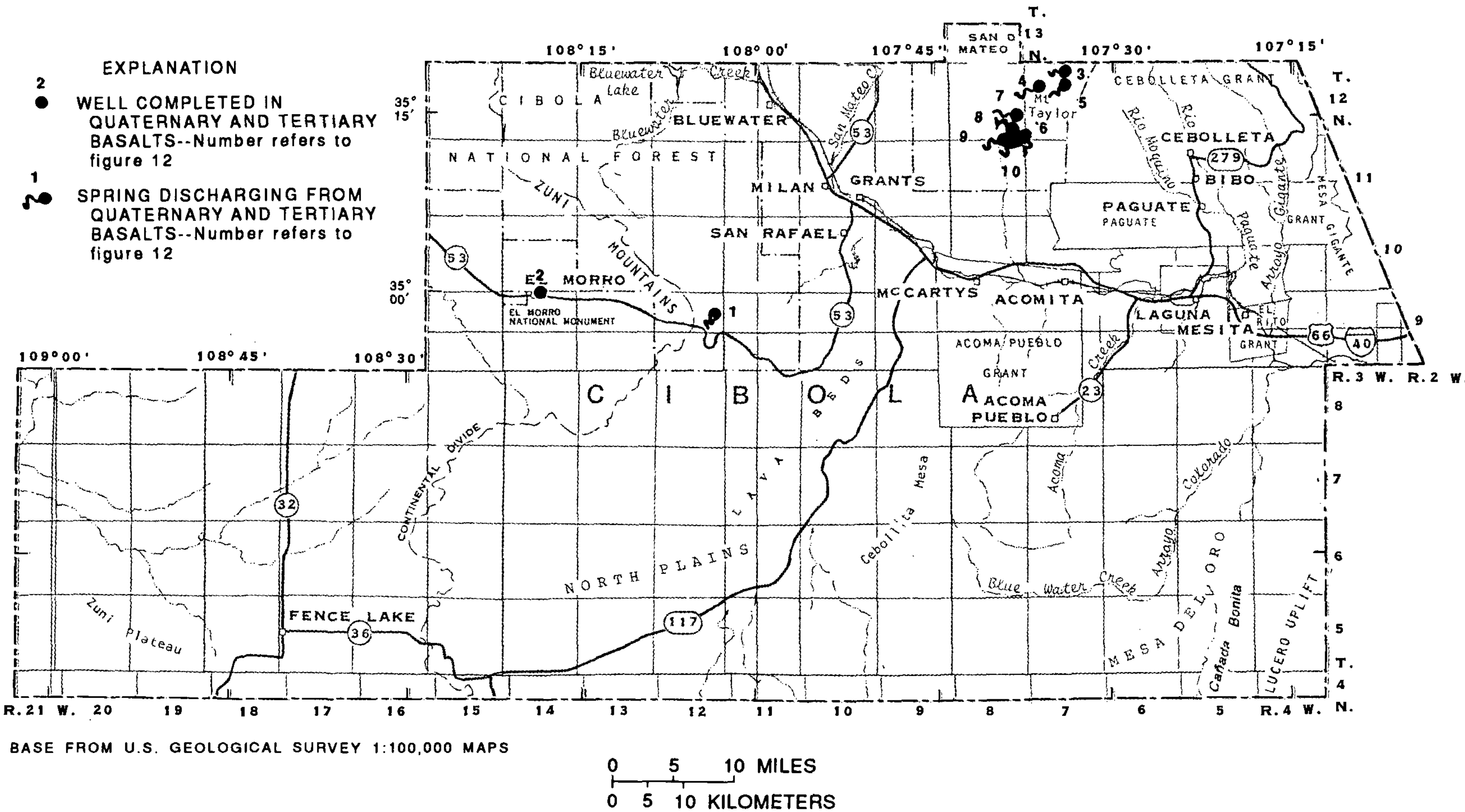


Figure 11.--Well completed in and springs discharging from Quaternary and Tertiary basalts in the Zuni Mountains and in the Mount Taylor area in Cibola County, New Mexico.

Limited water-quality data are available for ground water from Quaternary and Tertiary basalts. Dissolved-solids concentrations for nine springs shown in figure 12 were small, ranging from 86 to 170 milligrams per liter. The median concentration for dissolved solids was 100 milligrams per liter. This small dissolved-solids concentration of the water reflects the short residence time in volcanic strata and the nonreactive nature of volcanic rocks. Water-quality characteristics of water can be illustrated by trilinear diagrams. These diagrams show the chemical composition of water in terms of milliequivalent percentages of the major cations (calcium, magnesium, and sodium potassium) and the major anions (carbonate-bicarbonate, sulfate, and chloride). The predominant ions in water from springs in the Mount Taylor area are calcium, magnesium, and bicarbonate (fig. 12). The large magnesium content most likely results from movement of water through magnesium-rich volcanic material.

Sandstones in the Mesaverde Group

Saturated sandstone beds in the Mesaverde Group generally yield sufficient volumes of water for stock and domestic purposes. Mesaverde strata either are exposed at land surface or are overlain by alluvium or basalt. Local ground-water flow systems predominate where the deposits have been eroded to form arroyos, valleys, and mesas. Ground water, recharged by precipitation on topographically high areas, moves downgradient in shallow flow systems toward topographically low areas. Some downward-moving ground water is diverted horizontally by small-permeability clay or shale layers within the Mesaverde Group or by the Mancos Shale. This ground water may discharge as springs from outcrop areas. The most common occurrence of springs discharging from Mesaverde strata is at the Mancos Shale and Gallup Sandstone contact. Cebolla Spring (05.10.12.113), Little Cebollita Spring (05.10.12.141), and Marez Spring (05.19.07.334) (table 2) are examples of springs that discharge at this contact. Several other unnamed springs and seeps also emerge at this contact in other areas of the county. Recharge to Mesaverde Group aquifers in the vicinity of Mount Taylor probably is greater than in other areas because of the more permeable nature of the volcanic material overlying the sedimentary strata and the greater volumes of precipitation in the mountainous area.

Discharge from aquifers in the Mesaverde Group is by downward leakage to underlying units, evapotranspiration, springs, and pumpage of wells. Downward leakage may be limited because of the thick Mancos Shale deposits that underlie and intertongue with the Mesaverde Group. Discharge from individual springs usually is quite small. At Marez Spring (05.19.07.334), the discharge measured on October 14, 1980, was about 0.1 gallon per minute. These springs probably flow in response to precipitation; therefore, discharge could vary depending on precipitation during the year. Water also is withdrawn from Mesaverde aquifers by numerous stock and domestic wells. With the exception of two wells in the northeastern corner of the county, 09.03.13.422 and 11.07.35.421 (Risser and Lyford, 1983, table 1), all wells in the Mesaverde Group are in the southern and western parts of the county. Although some wells in the Fence Lake area are used for domestic purposes, the majority are used for stock watering.

Site number on figures 11,12	Location number	Dissolved-solids concentration, in milligrams per liter	Description
1	09.12.12.113	170	Spring
2	10.14.34.312	260	Well
3	12.07.03.434	130	Spring
4	12.07.08.322	86	Spring
5	12.07.10.414	100	Spring

Site number on figures 11,12	Location number	Dissolved-solids concentration, in milligrams per liter	Description
6	12.07.31.331	100	Spring
7	12.08.24.112	97	Spring
8	12.08.25.111	--	Spring
9	12.08.35.231	97	Spring
10	12.08.36.234	100	Spring

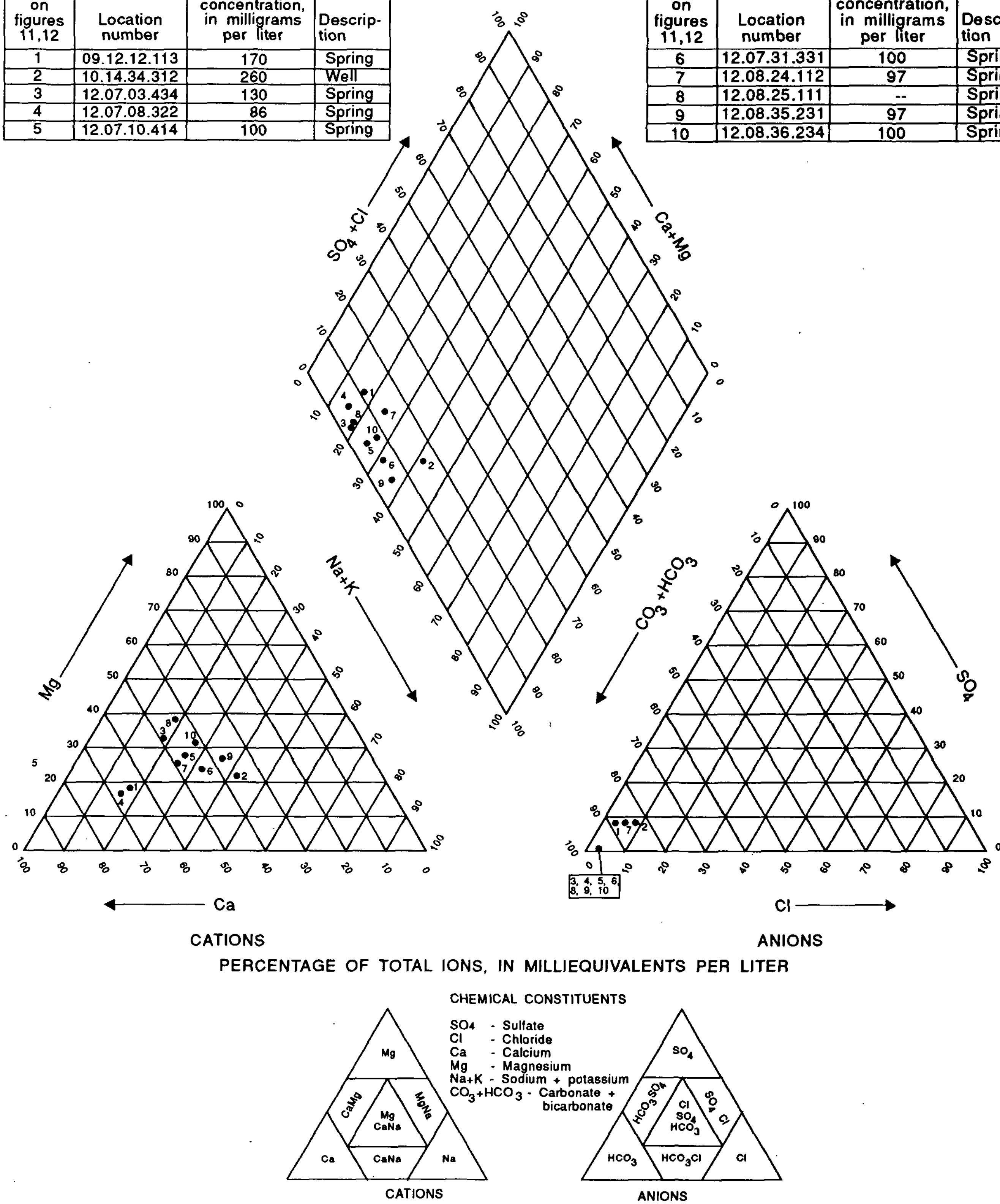


Figure 12.--Major dissolved solids in water from Quaternary and Tertiary basalts in the Zuni Mountains and in the Mount Taylor area, Cibola County, New Mexico.

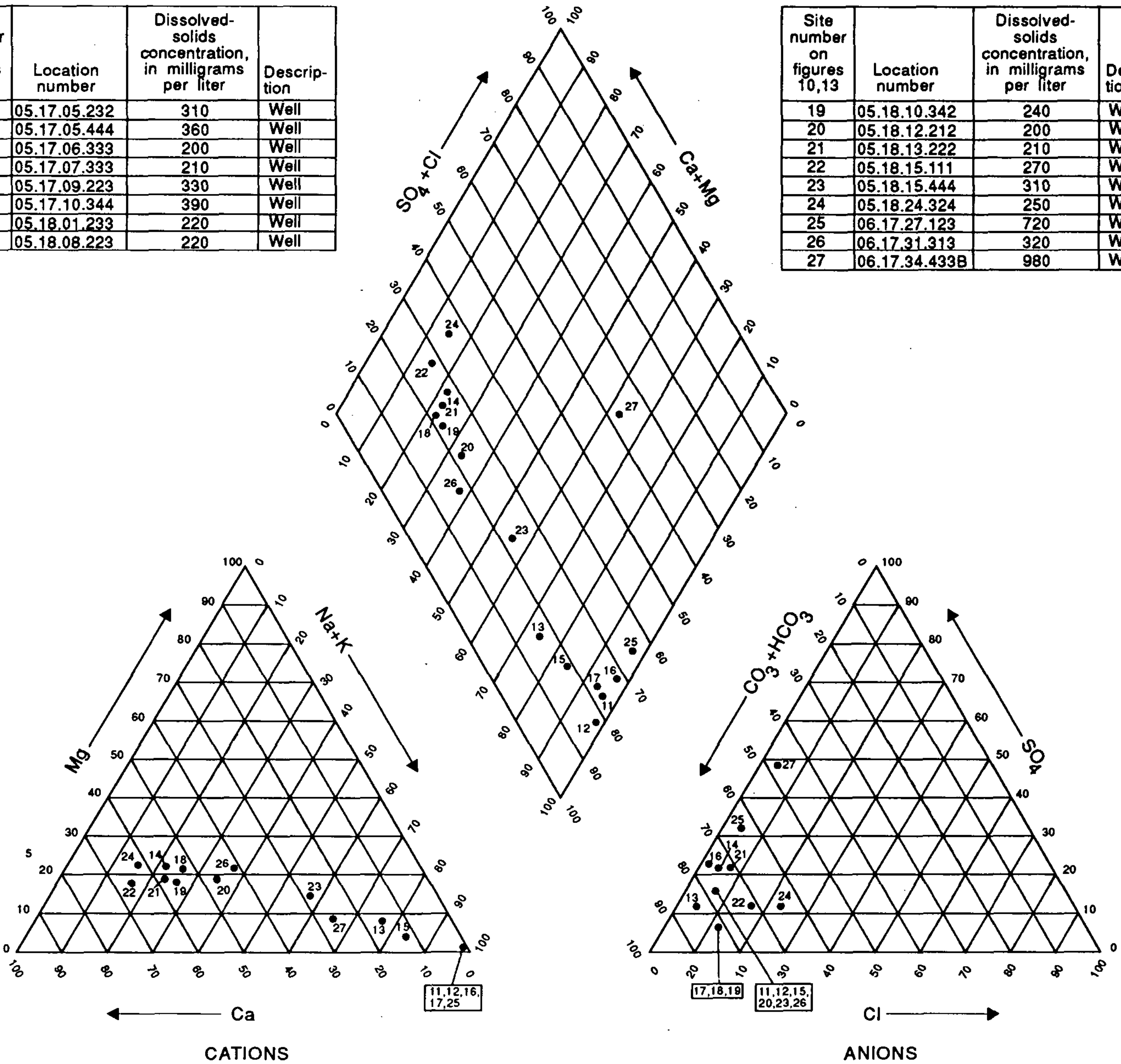
Twenty-three coal-test holes drilled by the New Mexico Bureau of Mines and Mineral Resources in the southwestern part of the county were completed in the Mesaverde Group (referred to as the Moreno Hill Formation, correlative with the Gallup Sandstone) (Hook and others, 1983). Cuttings and geophysical logs are available for most of these test holes. Some of the test holes that have shallow completion depths are near mesa edges or are on topographically high areas that reportedly were dry. Twenty-four coal-test holes drilled during June 1981 by Santa Fe Mining, Inc. also provide information on the Mesaverde Group in the southwestern part of the county. Lithologic and geophysical logs are available for these test holes. In addition to these test holes, 145 wells in the Mesaverde Group were inventoried during the present study, and information is available for 11 wells in the Mesaverde Group inventoried during an earlier Bureau of Indian Affairs study of the Ramah Navajo Indian Reservation. Information on wells in the Mesaverde Group is listed in table 2. Individual well yields range from less than 1 to about 5 gallons per minute. Most wells in the Mesaverde Group are equipped with windmills and piston pumps. Larger pumping rates may be possible with larger capacity pumps.

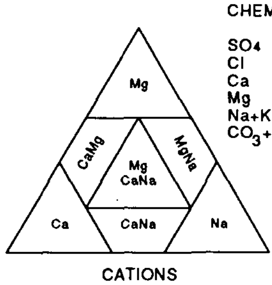
Information is not available to define aquifer properties of saturated sandstones within the Mesaverde Group. Although water-level measurements were obtained for many of the wells, potentiometric-surface maps could not be prepared for the saturated sandstones because of the large variations in hydraulic head among the various sandstone units. Well yields from Mesaverde sandstones range from less than 1 to 12 gallons per minute. The larger yields generally reflect the use of submergible pumps, whereas the smaller yields generally are associated with windmills.

Water-quality information for 17 wells in the Mesaverde Group located in the Jaralosa Draw drainage basin is shown in figure 13. The location of the wells within the drainage basin is shown in figure 10. Water-level information for these wells indicates that ground water moves from topographically high areas toward Jaralosa Draw and Lorenzo Arroyo in shallow flow systems. Calcium bicarbonate and sodium bicarbonate waters predominate in the drainage area. The predominant cation species is related to the position of the well in the drainage basin as shown in figures 10 and 13. Wells in the Mesaverde Group that are away from drainages (sites 14, 18, 19, 21, 22, and 24, figs. 10 and 13) contain calcium as the predominant cation; water in wells in the Mesaverde Group along Jaralosa Draw and Lorenzo Arroyo (sites 11, 12, 16, 17, and 25, figs. 10 and 13) contain sodium as the predominant cation. As ground water in the basin moves downgradient, it becomes enriched in sodium, probably by the ion-exchange process. Thus, ground water near arroyos, which probably has been in the flow system for the longest time, has larger sodium concentrations than ground water near drainage divides. Other possible mechanisms of sodium enrichment could include leaching of sodium or precipitation of calcium carbonates that results in a relative increase in sodium ions (Lee, 1981, p. 11). Neither of these two mechanisms is believed to be as important as the ion-exchange process. Geochemical data indicate that the percentage of bicarbonate ions remains relatively constant regardless of the well location within the basin (fig. 13). Apparently, recharge water from precipitation is sufficiently charged with bicarbonate ions to maintain bicarbonate concentrations throughout the flow path. Small sulfate percentages indicate that gypsum is not present in sufficient quantity to produce a sulfate water (fig. 13). Where deposits of the Mesaverde Group are of continental origin, only limited occurrences of gypsum would be expected. A similar geochemical environment probably exists in other small drainage areas in areas where the Mesaverde Group is present. Lee (1981, p. 5) noted similar sodium-enrichment trends in southeastern Montana, where ground water in shallow flow systems evolved from calcium-rich to sodium-rich water from recharge to discharge areas.

Site number on figures 10,13	Location number	Dissolved-solids concentration, in milligrams per liter	Description
11	05.17.05.232	310	Well
12	05.17.05.444	360	Well
13	05.17.06.333	200	Well
14	05.17.07.333	210	Well
15	05.17.09.223	330	Well
16	05.17.10.344	390	Well
17	05.18.01.233	220	Well
18	05.18.08.223	220	Well

Site number on figures 10,13	Location number	Dissolved-solids concentration, in milligrams per liter	Description
19	05.18.10.342	240	Well
20	05.18.12.212	200	Well
21	05.18.13.222	210	Well
22	05.18.15.111	270	Well
23	05.18.15.444	310	Well
24	05.18.24.324	250	Well
25	06.17.27.123	720	Well
26	06.17.31.313	320	Well
27	06.17.34.433B	980	Well





CHEMICAL CONSTITUENTS

SO_4 - Sulfate
Cl - Chloride
Ca - Calcium
Mg - Magnesium
Na+K - Sodium + potassium
CO_3+HCO_3 - Carbonate + bicarbonate

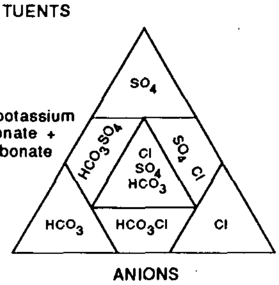


Figure 13.--Major dissolved solids in water from saturated sandstones in the Mesaverde Group in Cibola County, New Mexico.

Dakota-Zuni-Bluff Aquifer

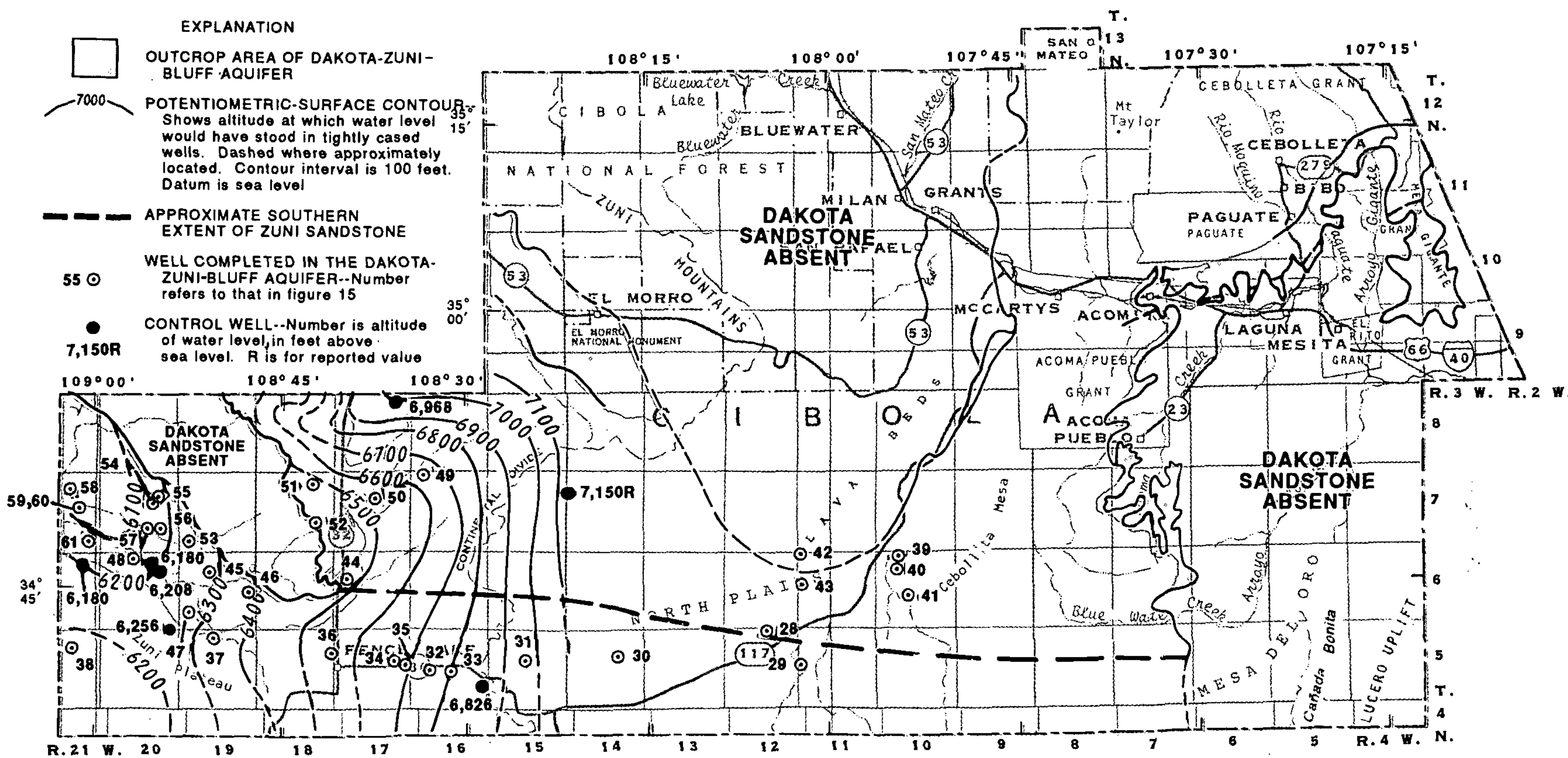
Sandstone tongues of the Dakota Sandstone, together with the Zuni Sandstone, Bluff Sandstone, and Jackpile Sandstone Member (Owen and others, 1984) of the Morrison Formation, are considered one aquifer in this report (fig. 14). In areas where the main body of the Dakota Sandstone overlies the Zuni Sandstone, a good hydraulic connection probably exists. Northeast of the Morrison pinch-out, the Zuni Sandstone merges with the Bluff Sandstone and is separated from the Dakota Sandstone by the Morrison Formation. In this area, the Zuni Sandstone probably is hydraulically connected with the Bluff Sandstone but is not in hydraulic connection with the Dakota Sandstone. The Jackpile Sandstone Member probably is hydraulically connected with the overlying basal Dakota Sandstone. In the central and western parts of Cibola County, the main body of the Dakota Sandstone and the Zuni Sandstone are believed to form a continuous hydrogeologic unit.

Sandstone tongues of the Dakota Sandstone overlying the main body of the Dakota may be only slightly hydraulically connected. The intervening tongues of the Mancos Shale have smaller values of hydraulic conductivity and retard the movement of water between tongues of the Dakota Sandstone. Data are not available to determine the hydraulic-head relation between the various tongues of the Dakota Sandstone.

Recharge to the Dakota-Zuni-Bluff aquifer occurs as infiltration and percolation from precipitation and surface runoff and from leakage from underlying and overlying units. Leakage from underlying units probably is limited to a small area in the southwestern corner of the county. Flow lines drawn normal to potentiometric-surface contours, shown in figure 14, indicate the direction of ground-water movement in the aquifer. In the northeastern part of the county, the potentiometric-surface contours of Ward and others (1982, pl. 16) indicate that ground water moves southeastward, away from the Mount Taylor area toward the Rio San Jose. The configuration of the contours in the vicinity of Mount Taylor indicates that this may be a recharge area for the Dakota-Zuni-Bluff aquifer in the northeastern part of the county.

Discharge from the aquifer in this part of the county is to alluvium in valleys near Paguate and to the Rio San Jose. Wells, springs, and open-pit mines also discharge in the Paguate area. Risser and Lyford (1983, p. 45) noted water-level declines of as much as 102 feet from 1959 to 1979 at well 10.05.05.142, completed in the Jackpile Sandstone Member. These declines are due in part to dewatering for the Anaconda P-10 underground mine near Paguate. The declines also may have been partly caused by ground-water discharge into open-pit mines constructed in the early 1950's.

In the western part of the county, potentiometric-surface contours indicate that ground water moves toward the west (fig. 14). Ground-water movement is influenced by the topography of the area: water moves from topographically high areas along the Continental Divide and the Zuni Plateau to topographically low areas. A comparison of potentiometric-surface contours for the Dakota-Zuni-Bluff and San Andres-Glorieta aquifers (see figs. 14 and 20) indicates that upward leakage from the San Andres-Glorieta aquifer to the Dakota-Zuni-Bluff aquifer may occur along the Ojo Caliente Monocline. Yields from stock and domestic wells completed in the Dakota-Zuni-Bluff aquifer generally range from less than 1 to about 16 gallons per minute. One domestic well had a reported yield of about 30 gallons per minute.



BASE FROM U.S. GEOLOGICAL SURVEY 1:100,000 MAPS

0 5 10 MILES

0 5 10 KILOMETERS

Figure 14.--Outcrop areas and potentiometric-surface contours of the Dakota-Zuni-Bluff aquifer, and approximate southern extent of the Zuni Sandstone in Cibola County, New Mexico.

Water-quality information for 34 water samples is shown in figure 15. These water samples were collected from wells in the western half of the county. Dissolved-solids concentrations in water from 34 wells range from 220 to 2,000 milligrams per liter. The analyses indicate calcium sulfate and sodium bicarbonate as the predominant water types with some sodium calcium bicarbonate water present. These two predominant water types generally occur in two different geologic environments. The presence of a thick section of Mancos Shale, where calcium is exchanged for sodium as water moves downward toward the Dakota-Zuni-Bluff aquifer, may determine whether the water sample is sodium rich. Sodium bicarbonate water occurs where the Dakota-Zuni-Bluff aquifer is overlain by the main body of the Mancos Shale, whereas calcium sulfate water occurs where the main body of the Mancos has been removed by erosion.

Westwater Canyon Aquifer

The Westwater Canyon Member of the Morrison Formation and sandstones of the overlying Brushy Basin Member of the Morrison Formation form the Westwater Canyon aquifer. Because of the small hydraulic conductivity of the fine-grained material in the Brushy Basin Member, Westwater Canyon sandstones are not hydraulically connected with the Jackpile Sandstone Member (Owen and others, 1984). The Jackpile Sandstone Member is believed to be hydraulically connected with the Dakota Sandstone and is therefore included in the Dakota-Zuni-Bluff aquifer.

The Westwater Canyon aquifer is a productive hydrologic unit in the northeastern part of the county. The aquifer is confined below by the Recapture Member and above by fine-grained sedimentary rocks of the Brushy Basin Member. Some recharge to the aquifer occurs on outcrop areas in McKinley County northeast of Grants. However, most recharge probably occurs through leakage from overlying and underlying units. Lyford and others (1980, fig. 2) stated that ground water in the Morrison Formation moves east and southeast out of McKinley County. A small part of the flow moves into northeastern Cibola County where it discharges to low-lying areas of the Rio Puerco and Rio San Jose Valleys. Much of this discharge probably is derived from upward leakage from the aquifer, although some spring discharge occurs from Westwater Canyon outcrops in adjacent areas of southwestern Sandoval County.

In the northeastern part of Cibola County, 39 wells completed in the Morrison Formation are used for stock, domestic, and industrial purposes. Most of the water produced from these wells is from the Westwater Canyon Member, although some is from sandstone beds in the lower part of the Brushy Basin Member. Risser and Lyford (1983, table 1) listed 12 wells completed in the Morrison Formation. Most of these wells probably withdraw water from the Westwater Canyon Member. A well field about 5 miles east of Seboyeta contains 18 wells that are completed in the Morrison Formation. Most of the water produced by these wells probably also is from Westwater Canyon sandstones. The water has been used for uranium milling. A group of nine wells in the Westwater Canyon in 12.04.05.000, 12.04.15.000, and 12.04.22.000 was used for exploration and testing purposes in development of a uranium mine.

Aquifer tests of wells in the Morrison Formation have been completed at several locations in Cibola County. Ward and others (1982, table 1) listed transmissivity values that range from 4 to 490 feet squared per day for seven wells and storage coefficients that range from 1.2×10^{-4} to 2×10^{-4} for four wells. Specific capacities for 20 wells in the Morrison Formation range from 0.05 to 3.7 gallons per minute per foot of drawdown, with a median of 0.5 gallon per minute per foot of drawdown. Pumping rates for these 20 wells range from 6 to 85 gallons per minute with a median of 38 gallons per minute. Larger production may be possible in some areas; well 11.05.27.322 (table 2) has a reported pumping rate of 100 gallons per minute from the Morrison Formation (Risser and Lyford, 1983, table 1).

Site number on figures 14,15	Location number	Dissolved-solids concentration, in milligrams per liter	Description
28	05.12.04.112	420	Well
29	05.12.13.141	450	Well
30	05.14.15.334	260	Well
31	05.15.16.223	220	Well
32	05.16.19.141	370	Well
33	05.16.21.242	590	Well
34	05.17.13.132A	370	Well
35	05.17.14.443	370	Well
36	05.18.13.444	630	Well
37	05.19.04.444B	330	Well
38	05.21.10.112B	230	Well
39	06.10.06.121	310	Well
40	06.10.07.232	730	Well
41	06.10.20.114	1,200	Well
42	06.12.01.311	310	Well
43	06.12.13.421	290	Well
44	06.17.19.131	220	Well

Site number on figures 14,15	Location number	Dissolved-solids concentration, in milligrams per liter	Description
45	06.19.16.113	390	Well
46	06.19.24.421	290	Well
47	06.19.29.231	1,700	Well
48	06.20.04.233	2,000	Well
49	07.16.06.314	830	Well
50	07.17.16.214	1,000	Well
51	07.18.11.234	450	Well
52	07.18.26.442	410	Well
53	07.19.31.411	550	Well
54	07.20.14.212A	280	Well
55	07.20.14.213	310	Well
56	07.20.26.334	760	Well
57	07.20.27.112	1,300	Well
58	07.21.10.332	1,100	Well
59	07.21.26.111	1,000	Well
60	07.21.26.141A	950	Well
61	07.21.36.222	850	Well

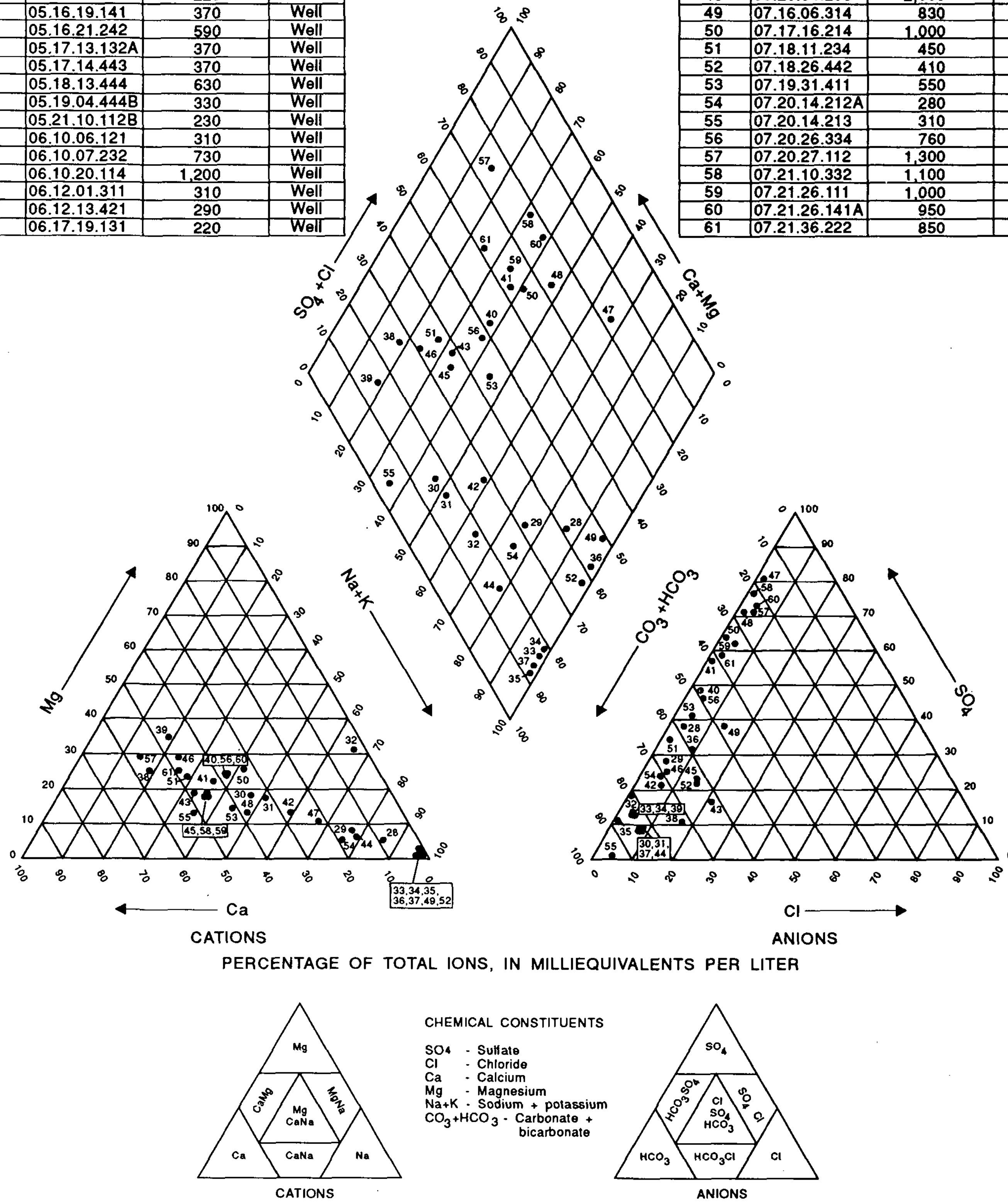


Figure 15.--Major dissolved solids in water from the Dakota-Zuni-Bluff aquifer in western Cibola County, New Mexico.

Water-quality information for the Westwater Canyon aquifer is available from Brod and Stone (1981), Ward and others (1982), Risser and Lyford (1983), and Stone and others (1983). Dissolved-solids concentrations in the Paguate area range from 500 to 1,500 milligrams per liter; dissolved-solids concentrations are larger toward the east. Trilinear diagrams (Ward and others, 1982, fig. 9) show that the water can be classified as a sodium bicarbonate sulfate water having dissolved-sodium concentrations that range from 150 to 450 milligrams per liter and sulfate concentrations that range from 190 to 480 milligrams per liter.

Todilto-Entrada Aquifer

The Entrada Sandstone and Todilto Limestone may form a hydraulically connected aquifer in the northeastern part of the county. The Rock Point Member of the Wingate Sandstone also may be in hydraulic connection with these units south of the Rio Puerco. The system is confined below by small-permeability sediments of the Chinle Formation and is separated from the overlying Dakota-Zuni-Bluff aquifer by the small-permeability deposits of the Summerville Formation.

Aquifer properties, well-completion schedules, direction of ground-water movement, and water quality for the Todilto-Entrada aquifer have been discussed in several studies (Lyford, 1979; Ward and others, 1982; Risser and Lyford, 1983). Results of these studies are summarized here. Recharge enters the Todilto-Entrada aquifer on outcrop areas south of the Rio San Jose and by leakage from underlying and overlying units. Ground water in the Todilto-Entrada aquifer moves from north and south of the Rio San Jose and discharges to alluvium in the Rio San Jose Valley. Thirteen wells have been completed in the Todilto-Entrada aquifer; most are in the vicinity of Laguna (Risser and Lyford, 1983, table 1). Reported well yields from the Todilto-Entrada aquifer are small, ranging from less than 1 to 3 gallons per minute. Most water from this aquifer is marginally suitable for stock; dissolved-solids concentrations range from 700 to 3,000 milligrams per liter for the 13 wells. The greater specific conductance mainly is due to solution of evaporite deposits in the Todilto Limestone.

Water-quality information is available for well number 09.14.06.111 completed in the Rock Point Member. Water from this well contained 250 milligrams per liter of dissolved solids and is a sodium calcium bicarbonate water.

Rock Point Member of the Wingate Sandstone

Few wells are known to be completed in the Rock Point Member in Cibola County. Gordon (1961, p. 32) listed well 09.09.05.214 as withdrawing water from the Rock Point Member, and Orr (1987, p. 5) listed one well (10.18.22.333B) that is completed in the Rock Point Member. Well 10.18.22.333B is about 8 miles north of Cibola County on Zuni tribal lands. In the vicinity of El Morro, where the Rock Point Member is about 200 feet thick, four test holes completed in this unit for the National Park Service were dry (table 2). Three other wells in the El Morro area, 09.14.05.214, 09.14.18.241, and 09.15.01.311 (table 2), withdraw water from the Rock Point Member. Well-yield and water-level information is not available for wells completed in the Rock Point Member.

Sandstones in the Chinle Formation

Wells completed in saturated sandstone beds in the Chinle Formation provide water for stock, domestic use, and in some areas, irrigation. Direct recharge to the sandstone beds occurs from precipitation and surface runoff along outcrop areas in the Zuni Mountains and along the Lucero Uplift. Downward leakage from overlying sediments also supplies water to the Chinle sandstones, but this component of recharge probably is small because of small-permeability mudstones and siltstones interbedded within the sandstones. Ground water in Chinle sandstones may be confined in areas where the formation is buried by overlying, small-permeability strata.

Ground water moves radially outward from the Zuni Mountains and flows downgradient along the sandstone beds. The rate of ground-water movement may be greater in the areas where major Triassic streams once existed than in other areas where Chinle sandstones occur (see fig. 19). Flow systems in the western two-thirds of the county may be regional in nature and have long flow paths. Discharge areas for flow systems in the Chinle originating in the Zuni Mountains are not well known. Near the mountains, small volumes of water probably leak downward to recharge the underlying San Andres-Glorieta aquifer. Away from the mountains, the gradients reverse and upward leakage from the San Andres-Glorieta aquifer to Chinle strata dominates. Sufficient hydraulic-head data are not available to determine where the transition occurs nor are data available to construct potentiometric-surface contours for saturated Chinle strata. Orr (1987, p. 16) stated that on Zuni tribal lands north of the panhandle, some water moves westward in a regional flow system in the Chinle. Faulting has created areas where recharge to and discharge from the Chinle can occur. In the Grants-Bluewater area, the offset might be several hundreds of feet along normal faults and might bring permeable sandstone beds in contact with interbedded siltstones and mudstones that have small permeability. Ground water may move up or down these fault zones depending on hydraulic-head relations. Structural movement along the Ojo Caliente Monocline has offset Chinle strata as much as 1,200 feet. The effect of this displacement on the regional flow system in the Chinle is not known.

In the eastern third of the county the Chinle Formation is believed to function as a small-permeability confining unit in which no significant regional ground-water flow system exists. Ground water in local flow systems in the Correo Sandstone Bed of the Petrified Forest Member of the Chinle Formation moves toward the Rio San Jose Valley (Risser, 1982, fig. 17). Recharge from precipitation and surface runoff, which infiltrate exposed Chinle strata in the Lucero Uplift, moves westward downdip along permeable sandstone beds to discharge to valleys adjacent to the uplift. Scattered springs issuing from Chinle strata are evidence for discharge in this area. Upward leakage from the San Andres-Glorieta aquifer also may contribute to spring discharge from Chinle strata in the eastern part of the county.

Wells completed in Chinle sandstones are in three general areas of the county: the northwestern part of the panhandle, the Grants-Bluewater area, and the eastern side (fig. 16). These groupings reflect the relatively shallow depth of saturated Chinle sandstones and the absence of more suitable aquifers close to land surface. In the northwestern part of the panhandle area, a group of wells is completed in the Chinle at depths that range from 200 to 1,460 feet. The deepest wells probably are completed in the Sonsela Sandstone Bed. Head data are not available to construct potentiometric-surface contours. However, on Zuni tribal lands adjacent to Cibola County, Orr (1987, p. 16) showed that ground water in Chinle strata moves westward, in the same direction that ground water moves in the underlying San Andres-Glorieta aquifer. In the central part of the county, site 81 (figs. 16 and 17) is believed to be completed in Chinle strata. In this area, erosion has removed most Chinle strata from the Zuni Uplift (pl. 1), thus the well probably is completed in basal Chinle strata.

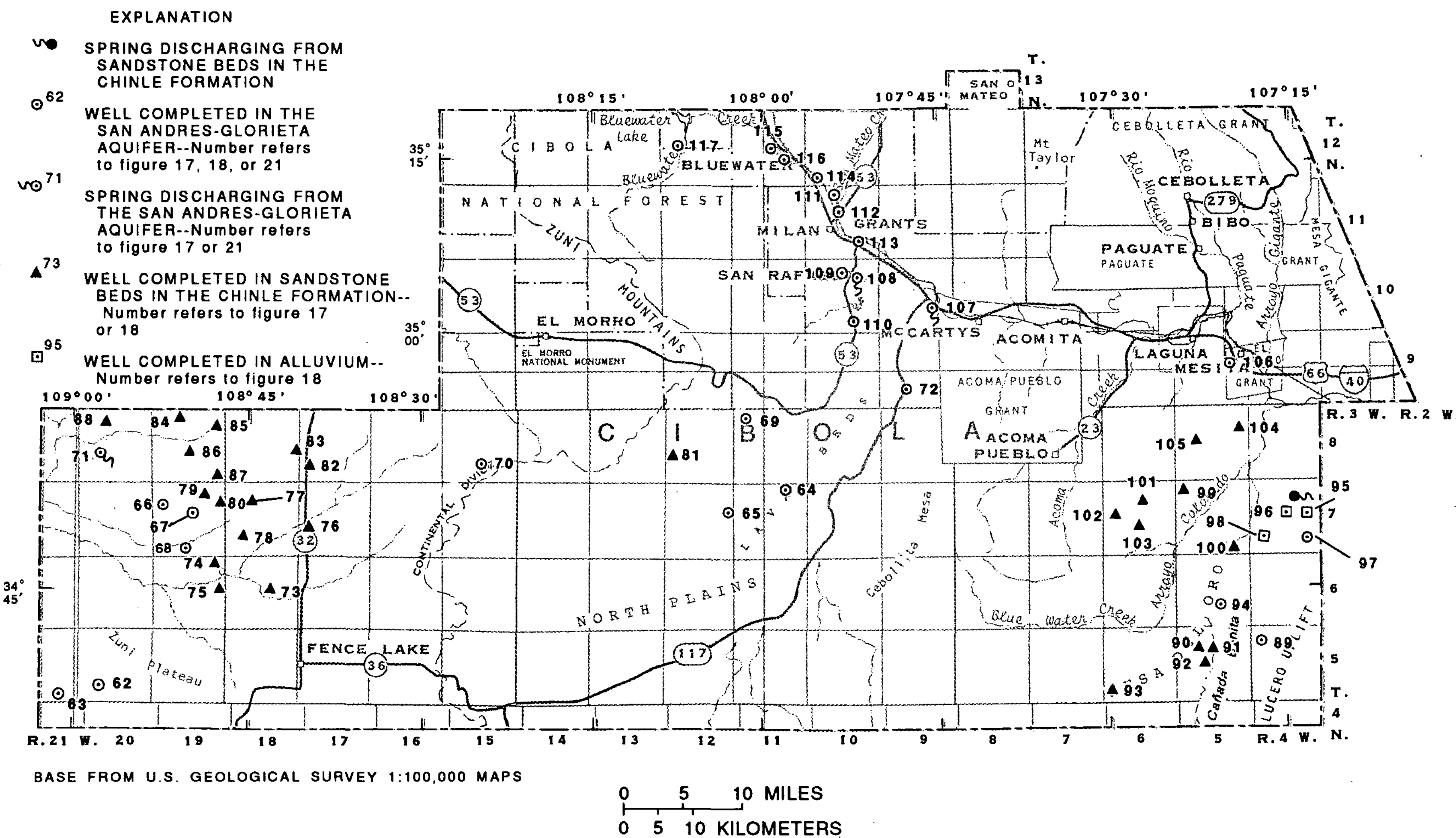
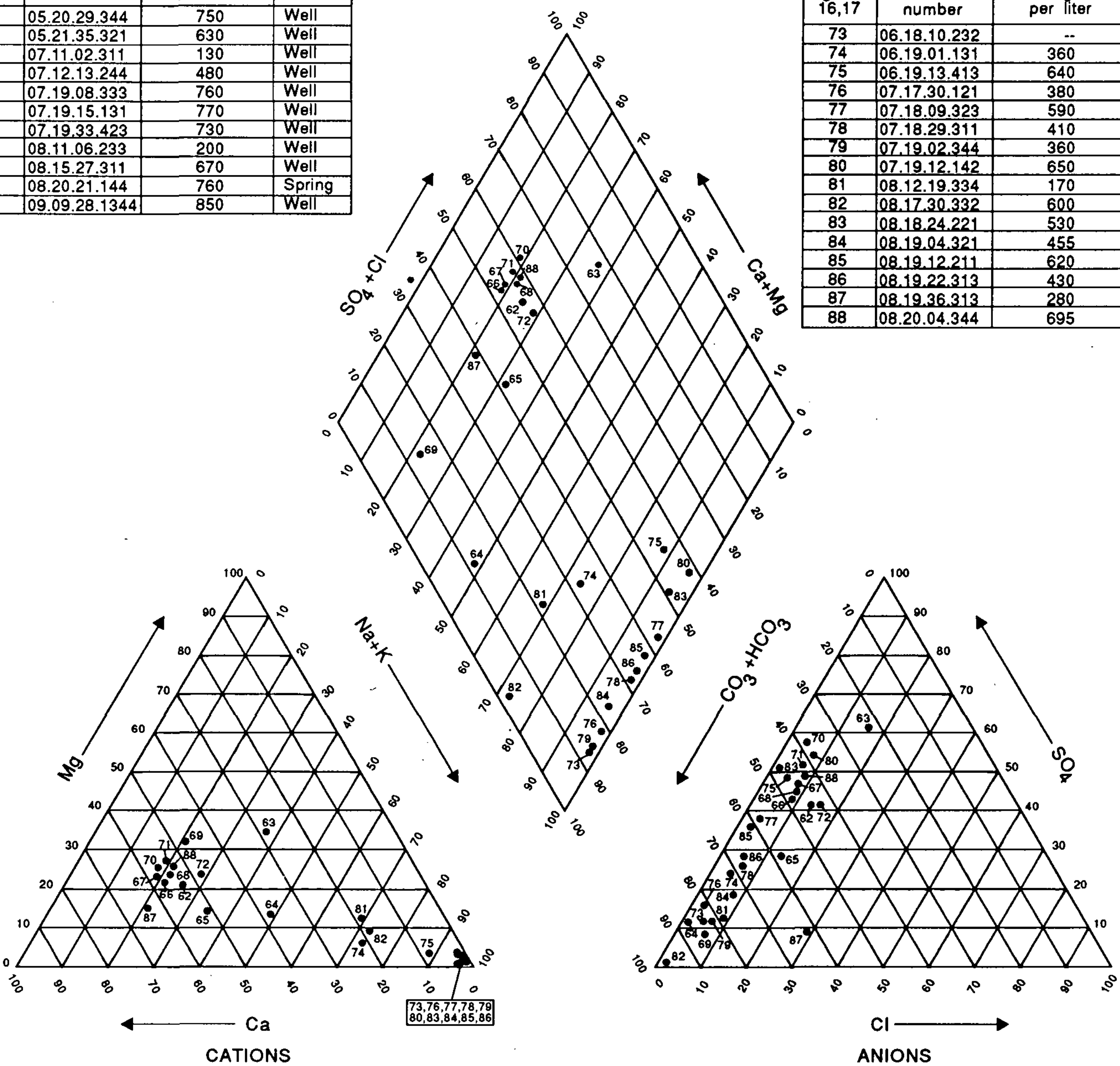


Figure 16.--Selected wells completed in the San Andres-Glorieta aquifer, sandstone beds in the Chinle Formation, and alluvium in Cibola County, New Mexico.

San Andres-Glorieta aquifer			
Site number on figures 16,17	Location number	Dissolved-solids concentration, in milligrams per liter	Description
62	05.20.29.344	750	Well
63	05.21.35.321	630	Well
64	07.11.02.311	130	Well
65	07.12.13.244	480	Well
66	07.19.08.333	760	Well
67	07.19.15.131	770	Well
68	07.19.33.423	730	Well
69	08.11.06.233	200	Well
70	08.15.27.311	670	Well
71	08.20.21.144	760	Spring
72	09.09.28.1344	850	Well

Sandstone beds in the Chinle Formation			
Site number on figures 16,17	Location number	Dissolved-solids concentration, in milligrams per liter	Description
73	06.18.10.232	--	Well
74	06.19.01.131	360	Well
75	06.19.13.413	640	Well
76	07.17.30.121	380	Well
77	07.18.09.323	590	Well
78	07.18.29.311	410	Well
79	07.19.02.344	360	Well
80	07.19.12.142	650	Well
81	08.12.19.334	170	Well
82	08.17.30.332	600	Well
83	08.18.24.221	530	Well
84	08.19.04.321	455	Well
85	08.19.12.211	620	Well
86	08.19.22.313	430	Well
87	08.19.36.313	280	Well
88	08.20.04.344	695	Well



PERCENTAGE OF TOTAL IONS, IN MILLIEQUIVALENTS PER LITER

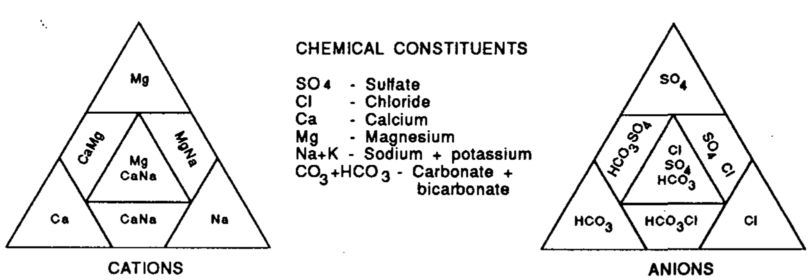


Figure 17.--Major dissolved solids in water from the San Andres-Glorieta aquifer and sandstone beds in the Chinle Formation in western Cibola County, New Mexico.

Water-quality information for water from site 81 and wells completed in the Chinle in the northwestern part of the panhandle is shown in figure 17. For the purpose of comparison, waters from the San Andres-Glorieta aquifer and saturated sandstone beds in the Chinle Formation in the western part of the county are plotted together in figure 17. Water in Chinle strata generally is a sodium bicarbonate or a sodium bicarbonate sulfate water that has small calcium and chloride percentages (fig. 17). The increased sodium concentrations in the Chinle probably are due to ion-exchange reactions that occur in interbedded shales and clays. In some cases where depths were not known, wells were determined to be completed in the Chinle because sampled water contained large percentages of sodium.

Water from six wells in the Chinle Formation (sites 74, 75, 81, 82, 87, and 88) shown in figure 17 has larger calcium concentrations than would normally be expected for water from the Chinle. These calcium-rich waters are characteristic of water from wells completed in basal sections of the Chinle where mixing of water from the Chinle and San Andres-Glorieta aquifer might occur. Site 87, which is completed above the Sonsela Sandstone Bed, probably withdraws water from a limestone bed in the Chinle Formation. Water from this well has calcium and magnesium concentrations that are similar to those found in water from the San Andres-Glorieta aquifer. Dissolved-solids concentrations in water from this group of wells in the Chinle range from 170 to 695 milligrams per liter (fig. 17). Site 81, from which water has a dissolved-solids concentration of 170 milligrams per liter, is close to the Chinle outcrop area. Water from wells farther east has large dissolved-solids concentrations, reflecting long residence times.

A second group of wells in the Chinle in the Grants-Bluewater area, inventoried by Gordon (1961), is shown in figure 16. Well depths in this area range from 98 to 1,035 feet, and the median depth is 200 feet. The Chinle dips east and northeast away from the Zuni Mountains in the Grants-Bluewater area, and wells progressively farther from the uplift must be drilled deeper to reach Chinle sedimentary rocks. Wells 10.09.23.134 and 10.09.26.433 are completed at depths of 1,035 and 965 feet, respectively. Most wells in the Chinle Formation in the Grants-Bluewater area probably are completed in middle and lower sandstone beds of the formation. A potentiometric-surface map could not be completed for water levels in wells in the Chinle in this area because of complex faulting and lack of hydraulic-head data, although ground water probably moves generally eastward. Upward leakage may occur along faults where water-yielding Chinle strata are under confined conditions.

Detailed water-quality information for water from wells in the Chinle in the Grants-Bluewater area is not available. Dissolved-solids concentrations from Gordon (1961, table 10) range from approximately 500 milligrams per liter for water from well 12.11.03.112A to approximately 18,000 milligrams per liter for water from well 12.10.01.222. This wide range in specific conductance reflects the complex and highly varied nature of flow systems in the Chinle strata and of the strata themselves. Like water from other wells in the Chinle, sodium concentrations are large, accounting for 83 to 97 percent of total cations.

A third group of wells in the Chinle is along the eastern side of the county in Tps. 8 and 9 N. (fig. 16). Wells in this area were inventoried during this study and by Risser (1982). These wells are completed in the Correo Sandstone Bed, which is believed to occur only locally in this area. Wells south of T. 8 N. are completed at varying depths in the Chinle Formation.

Water-quality information for water in the Chinle in the eastern part of the county is shown on a trilinear diagram (fig. 18). Water from wells completed in the Correo Sandstone Bed, in the upper part of the section, has smaller sodium percentages than water from sandstones lower in the Chinle section. The water types range from a sodium bicarbonate to a sodium calcium bicarbonate sulfate water. Dissolved-iron concentrations range from 2,200 to 22,000 micrograms per liter in water from sites 90, 91, 92, and 96 (fig. 18). Site 105 (figs. 16 and 18), which has a sodium chloride type water, is perforated near the base of the Chinle Formation. Water from this flowing well may be derived partly from upward leakage from the San Andres-Glorieta aquifer.

Dissolved-boron concentrations in some water in the Chinle Formation exceed the U.S. Environmental Protection Agency (1976) recommended limit of 750 micrograms per liter for irrigation water. Hem (1970, p. 187) stated that water in volcanic areas and in many thermal springs may contain considerable concentrations of boron. Tuffaceous sandstones and bentonitic clays in the Chinle Formation are of volcanic origin and are possible sources of the dissolved boron. In the northwestern part of the panhandle, larger boron concentrations seem to occur in water from the Sonsela Sandstone Bed. This association cannot be made for boron in water from the Chinle Formation in the eastern part of the county. Dissolved-boron concentrations in water generally are larger in the eastern part of the county, with a median value of 780 micrograms per liter, than in the western part of the county, with a median of 260 micrograms per liter. The small dissolved-boron concentrations in water from site 81 (fig. 16) may be due to the well's proximity to outcrop areas and to well completion in basal Chinle strata.

San Andres-Glorieta Aquifer

In Cibola County the Glorieta Sandstone and the San Andres Limestone are considered to be one aquifer because of the gradational contact and the probable substantial hydraulic connection between the units. The aquifer extends westward into Arizona, where it is termed the "Coconino aquifer" (Mann and Nemechek, 1983, p. 10), northward into McKinley County, eastward into Valencia County, and southward into Catron and Socorro Counties.

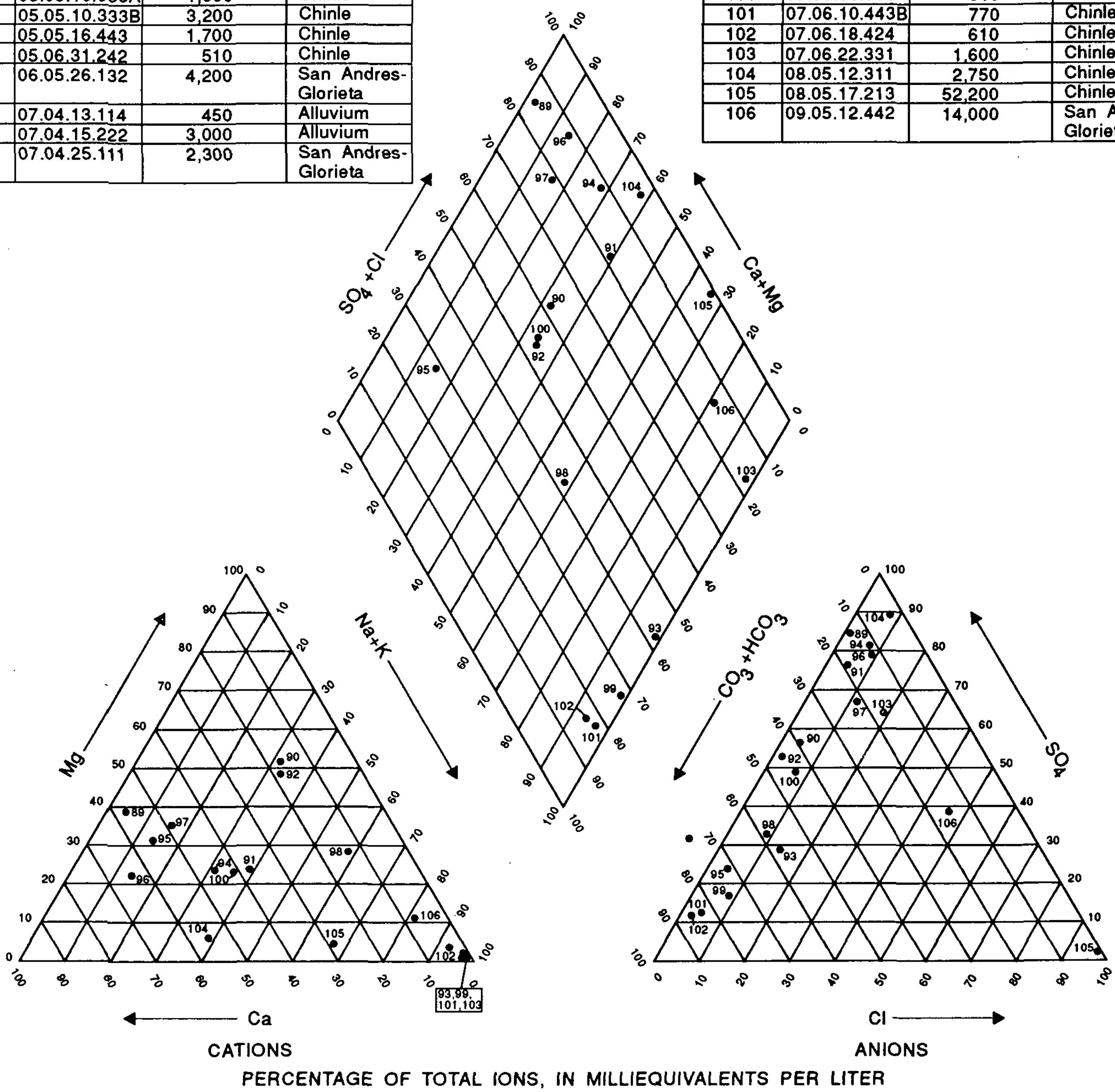
Data from oil-test holes and stock, municipal, and industrial wells indicate that the thickness of the aquifer ranges from about 200 feet along the northern border of Cibola County to about 720 feet at oil-test hole 04.05.17.140 in Socorro County, just south of the Cibola County border. The thickest part of the aquifer is in the southeastern corner of Cibola County where an evaporite basin existed during Permian time. The thicker sections of the San Andres-Glorieta in this area usually contain units of anhydrite and gypsum. The San Andres-Glorieta aquifer is absent in the central part of the Zuni Mountains and in the extreme southeastern corner of the county (fig. 19).

Depth to the top of the San Andres-Glorieta aquifer varies throughout the county. The aquifer crops out along the northeastern and southwestern flanks of the Zuni Mountains, along the Lucero Uplift in the southeastern corner of the county, and along the Ojo Caliente Monocline in the northwestern corner of the county (fig. 20). Depth to the top of the aquifer ranges from about 1,000 to 3,100 feet across much of the county.

Recharge to the San Andres-Glorieta aquifer occurs along outcrops on the flanks of the Zuni Mountains. Water moves downgradient along solution channels and fractures in the San Andres Limestone and to a lesser extent through interconnected pore spaces and fractures in the Glorieta Sandstone. Away from the Zuni Mountains, water in the aquifer is confined by small-permeability sedimentary rocks of the overlying Triassic Chinle Formation.

Site number on figures 16,18	Location number	Dissolved-solids concentration, in milligrams per liter	Aquifer
89	05.04.05.142	2,000	San Andres-Glorieta
90	05.05.10.333A	1,900	Chinle
91	05.05.10.333B	3,200	Chinle
92	05.05.16.443	1,700	Chinle
93	05.06.31.242	510	Chinle
94	06.05.26.132	4,200	San Andres-Glorieta
95	07.04.13.114	450	Alluvium
96	07.04.15.222	3,000	Alluvium
97	07.04.25.111	2,300	San Andres-Glorieta

Site number on figures 16,18	Location number	Dissolved-solids concentration, in milligrams per liter	Aquifer
98	07.04.29.421	420	Alluvium
99	07.05.06.221A	980	Chinle
100	07.05.36.333	810	Chinle
101	07.06.10.443B	770	Chinle
102	07.06.18.424	610	Chinle
103	07.06.22.331	1,600	Chinle
104	08.05.12.311	2,750	Chinle
105	08.05.17.213	52,200	Chinle
106	09.05.12.442	14,000	San Andres-Glorieta



CHEMICAL CONSTITUENTS

SO_4 - Sulfate
Cl - Chloride
Ca - Calcium
Mg - Magnesium
Na+K - Sodium + potassium
CO_3+HCO_3 - Carbonate + bicarbonate

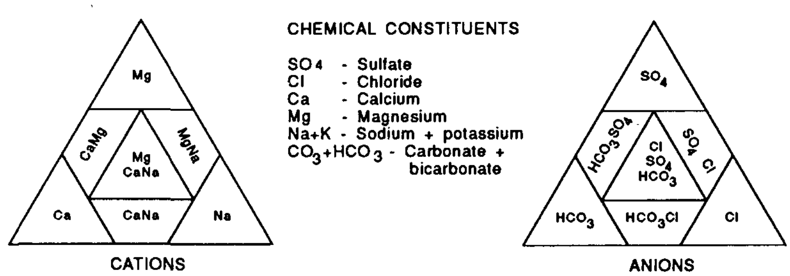


Figure 18.--Major dissolved solids in water from the San Andres-Glorieta aquifer, sandstone beds in the Chinle Formation, and alluvial material in eastern Cibola County, New Mexico.

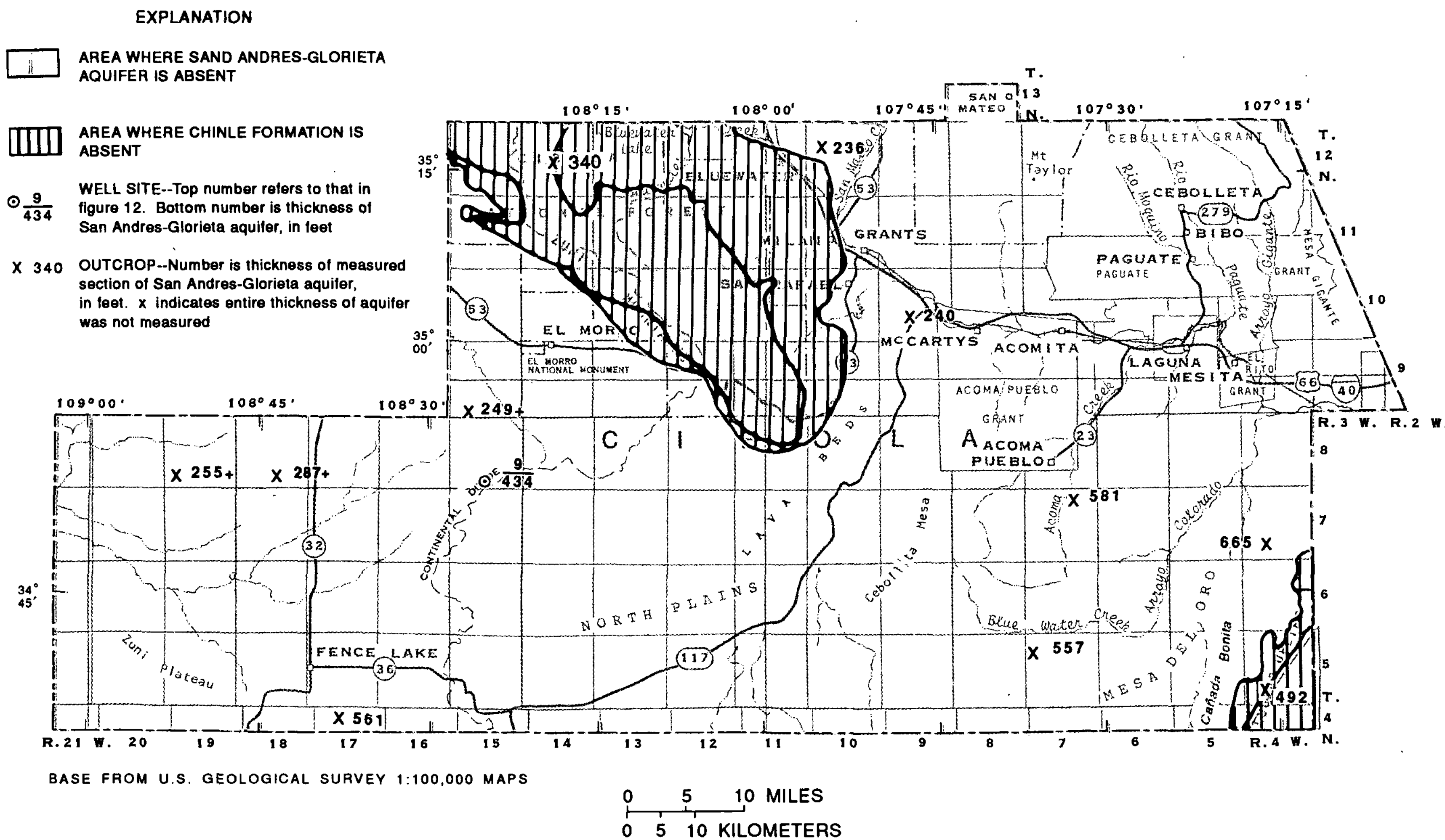


Figure 19.--Thickness of the San Andres-Glorieta aquifer at selected locations in Cibola County, New Mexico.

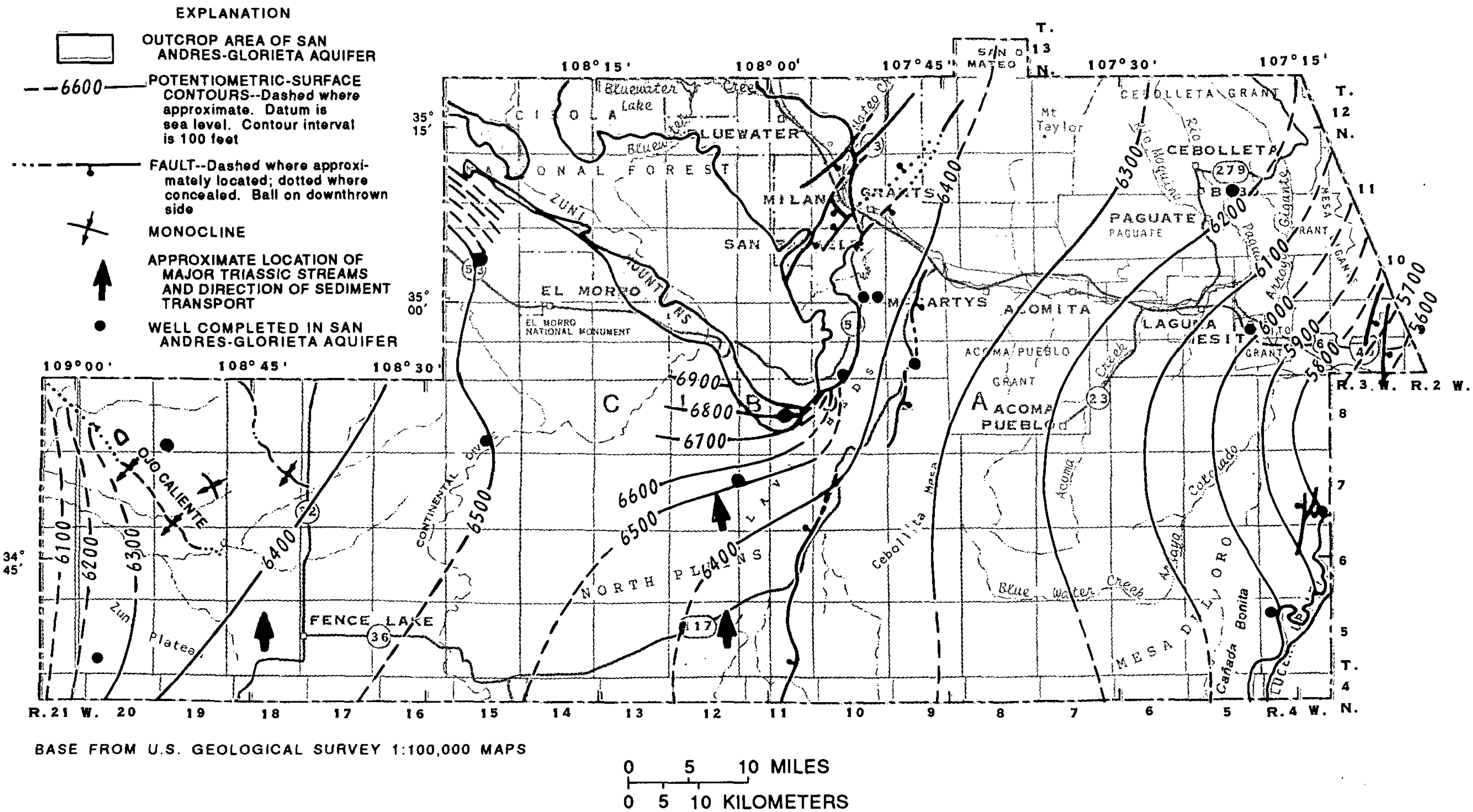


Figure 20.--Outcrop areas and potentiometric-surface contours of the San Andres-Glorieta aquifer in Cibola County, New Mexico.

Potentiometric-surface contours for the San Andres-Glorieta aquifer, representing data collected between 1975 and 1985, are shown in figure 20. Hydraulic-head data for this map are from stock, irrigation, and domestic wells, oil-test holes, and springs. Hydraulic-head data from six observation wells drilled under the supervision of the Geological Survey in 1986 and data points outside the county also were used to construct the map (Mann and Nemechek, 1983; Orr, 1987). The water-level contours shown on the map indicate that ground water generally moves radially from the Zuni Mountains.

Several topographic and structural features affect the movement of water through the aquifer. South of the Zuni Mountains, the Continental Divide appears to function as a ground-water divide; ground water moves toward the east and west, away from the divide. Water moving toward the west is further deflected by the Ojo Caliente Monocline. Southwest of the monocline ground water appears to be moving toward the west. Some ground water discharges from the system along the Ojo Caliente Monocline where the San Andres Limestone crops out. Orr (1987, p. 12) noted that an average combined discharge of 450 gallons per minute was measured from springs at 08.20.20.422 during 1979 and 1980.

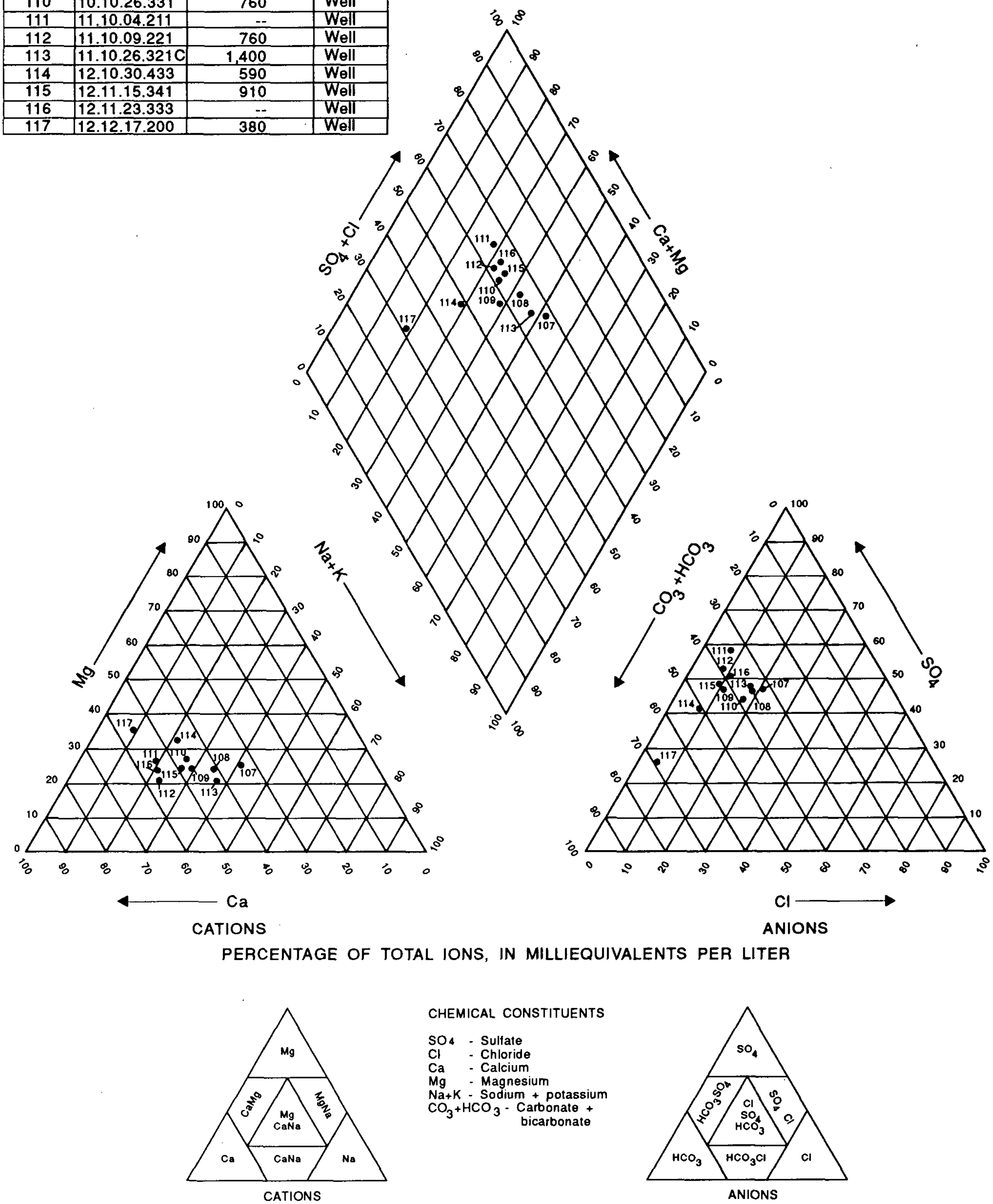
Ground-water discharge from the San Andres-Glorieta aquifer east of the Continental Divide is different from that west of the divide. Prior to extensive development of the aquifer, discharge in the Grants-Bluewater area was mostly from Ojo del Gallo Spring (site 108, fig. 16), estimated at 7 cubic feet per second (Morgan, 1938, p. 13). Domestic and stock wells also produced water from the San Andres-Glorieta aquifer, but this volume probably was small. Starting in 1944, irrigation wells began to withdraw water from the aquifer, and the discharge from Ojo del Gallo Spring began to decline as ground-water levels declined in the irrigated area (Gordon, 1961, p. 47). The number of irrigation wells increased from 7 in 1945 to 23 in 1954.

Total ground-water pumpage for irrigation, industrial, and municipal usage for 1954 was estimated to be about 14,100 acre-feet, of which irrigation accounted for about 90 percent (Gordon, 1961, table 7). During the next 26 years, the pattern of water use changed substantially. By 1980, many of the irrigation wells had been converted to industrial use for uranium milling and mining. Ground-water pumpage for irrigation had declined, and pumpage for municipal supply had increased. In 1980, the Bluewater-Toltec Irrigation District withdrew 1,620 acre-feet of ground water for irrigation (Sorensen, 1982, p. 37); 6,930 acre-feet of ground water was used for municipal supplies and industrial purposes (Charles Wohlenberg, New Mexico State Engineer Office, written commun., 1983). By 1982, ground-water pumpage for industrial use was reduced substantially to about 38 percent of 3,900 acre-feet pumped (New Mexico State Engineer Office, written commun., 1983).

In February 1983, a discharge of about 0.03 cubic foot per second at Ojo del Gallo Spring was noted, and by September 1984 a discharge of about 1.3 cubic feet per second was measured at the spring. The reappearance of discharge at Ojo del Gallo Spring probably was due to the decrease in ground-water pumpage and the accompanying rise in water levels in the Grants-Bluewater area.

Discharge at Horace Springs (site 107, fig. 16), which averages 4.9 cubic feet per second (Risser, 1982, p. 31), is another possible source of discharge from the San Andres-Glorieta aquifer in the Grants-Bluewater area. This discharge may represent water that is forced up along the fault at Grants and then moves eastward through the alluvium to discharge at Horace Springs.

Site number on figures 16,21	Location number	Dissolved-solids concentration, in milligrams per liter	Description
107	10.09.23.423	780	Spring
108	10.10.03.423	1,100	Spring
109	10.10.03.433A	700	Well
110	10.10.26.331	760	Well
111	11.10.04.211	--	Well
112	11.10.09.221	760	Well
113	11.10.26.321C	1,400	Well
114	12.10.30.433	590	Well
115	12.11.15.341	910	Well
116	12.11.23.333	--	Well
117	12.12.17.200	380	Well



CHEMICAL CONSTITUENTS

SO_4 - Sulfate
Cl - Chloride
Ca - Calcium
Mg - Magnesium
Na+K - Sodium + potassium
CO_3+HCO_3 - Carbonate + bicarbonate

Figure 21.--Major dissolved solids in water from wells and springs in the San Andres-Glorieta aquifer in the Grants-Bluewater area in Cibola County, New Mexico.

Ground water that continues to move east through the aquifer may leak upward to the overlying Chinle Formation sediments or leak downward to the underlying Pennsylvanian sedimentary rocks. The numerous springs discharging from Pennsylvanian sedimentary rocks just east of the Cibola County line indicate possible downward leakage of ground water out of the San Andres-Glorieta aquifer.

Aquifer properties for the San Andres-Glorieta aquifer system have been determined at several sites in the Grants-Bluewater area. Gordon (1961, p. 104) listed results of aquifer tests that were conducted at three pumped wells. All three wells are completed in the San Andres Limestone. Transmissivity ranges from 5.5×10^4 feet squared per day to 4.5×10^5 feet squared per day. Storage coefficients determined from measurements at observation wells were 4.7×10^{-4} and 9.7×10^{-4}.

Aquifer properties for the San Andres-Glorieta aquifer could not be determined elsewhere because there were no suitable wells for testing. Orr (1987, p. 13) reported the results of aquifer tests at three wells, all completed in the San Andres-Glorieta aquifer on Zuni tribal lands. These lands are adjacent to the western panhandle of Cibola County. Transmissivity at these wells ranges from 140 to 1,400 feet squared per day. These transmissivity values indicate that the San Andres-Glorieta aquifer is much less transmissive in this area than in the Grants-Bluewater area, probably because of a lack of karst features.

Aquifer characteristics in other areas of the county may be inferred from the spacing of the potentiometric contours shown in figure 20. West of the Continental Divide between the 6,500- and 6,400-foot contours, the hydraulic gradient is about 7.5 feet per mile. East of the Continental Divide, the hydraulic gradient between the 6,500- and 6,400-foot contours is about 3.8 feet per mile, and in T. 7 N., R. 5 W. between the 6,200- and 6,100-foot contours is about 23 feet per mile. The closely spaced contours and steep hydraulic gradients indicate areas of small transmissivity, whereas widely spaced contours and flatter hydraulic gradients indicate areas of large transmissivity. The San Andres-Glorieta aquifer in the Grants-Bluewater area and in the central and western parts of the county appears to be more transmissive than it is southwest of the Zuni Mountains and on the eastern side of the county.

The small-transmissivity area along the eastern side of the county may be due to large quantities of evaporite material in the aquifer. The San Andres Limestone in this area contains thick beds of anhydrite and gypsum that usually have small transmissivity. In addition, karst-type features may be more poorly developed in Permian rocks in this area.

Plots of chemical data for water samples collected from wells in the San Andres-Glorieta aquifer and from sandstone beds in the Chinle Formation in the western part of the county are shown in figure 17. Water from the San Andres-Glorieta aquifer is typically a calcium sulfate bicarbonate type in contrast to water from sandstones in the Chinle Formation that is a sodium bicarbonate sulfate type.

Water from the San Andres-Glorieta aquifer usually has small concentrations of sodium relative to calcium, whereas water from sandstone beds in the Chinle Formation usually has large concentrations of sodium relative to calcium (fig. 17). This characteristic was used, where well depths were not known, to distinguish whether the producing aquifer was the San Andres-Glorieta or sandstone beds in the Chinle Formation. Wells in which water appears to be a mixture of calcium and sodium type (sites 74, 75, and 82, figs. 16 and 17) may be completed in both aquifers. A comparison of figures 17 and 21 shows that water from the San Andres-Glorieta aquifer in the Grants-Bluewater area has chemical compositions similar to water from the San Andres-Glorieta aquifer in the western part of the State.

On the northeastern flanks of the Zuni Mountains, within or adjacent to the recharge area, dissolved-solids concentrations in water from wells range from 380 milligrams per liter (well 12.13.18.211) to 1,400 milligrams per liter (well 11.10.36.423). In an area southeast of the Zunis, dissolved-solids concentrations are slightly less, ranging from 130 milligrams per liter (site 64, figs. 16 and 17) to 480 milligrams per liter (site 65, figs. 16 and 17). Water from wells 06.05.28.421 and 05.04.06.321, approximately 30 miles southeast of the recharge area, contains dissolved-solids concentrations of 4,200 and 2,000 milligrams per liter, respectively. The larger values may be attributed to evaporite material found within the San Andres-Glorieta aquifer in the eastern part of the country. By contrast, the aquifer in the western part of the county was deposited in the marginal-marine-facies zone where deposits of evaporite materials are thin or absent, apparently resulting in water containing smaller dissolved-solids concentrations.

Water-level trends can indicate whether an aquifer is gaining or losing water in storage. Six water-level measurements from site 62 (fig. 16) were made from September 1980 through September 1983 (fig. 22). Water levels declined about 10 feet for the period shown in the hydrograph in figure 22. This decline may represent a decrease of water in storage that may be due to ground-water withdrawals for irrigation and for electrical-generating plants in adjacent Apache County, Arizona. Data are not available in other parts of the study area to determine long-term water-level trends.

Well yields from the San Andres-Glorieta aquifer are as much as 2,830 gallons per minute in the Grants-Bluewater area (Gordon, 1961, table 8). Few large-capacity wells have been completed in the aquifer in other areas of the county. Well 08.15.27.342 (Orr, 1987, table 2), completed in the San Andres-Glorieta aquifer, has a pumping rate of 88 gallons per minute. In adjacent Apache County, Arizona, yields of as much as 2,000 gallons per minute have been reported from wells in the Coconino Sandstone and Kaibab Limestone (Steven A. Smith, Salt River Project, written commun., 1982). On the basis of potentiometric-surface maps and water-quality information, well yields could be greater southwest of the Zuni Mountains than toward the east. In general, well yields probably would be greater in areas where regional structural features have produced faults and joints in the aquifer. Such areas occur adjacent to and include the Zuni Uplift and the Ojo Caliente Monocline.

Yeso Formation

In the Grants-Bluewater area, Yeso Formation strata occur at depths ranging from about 360 feet at well 11.11.05.232 to about 2,220 feet at oil-test hole 10.09.21.223. Gordon (1961, table 10) reported five wells completed in Yeso strata. The dissolved-solids concentration was 6,010 milligrams per liter in water from well 12.11.09.424, 6,500 milligrams per liter from well 12.11.16.230, and 346 milligrams per liter from well 12.11.20.422. Elsewhere in the county, depths to the top of the Yeso Formation range from 2,728 feet at oil-test hole 04.17.08.000 to 2,841 feet at oil-test hole 06.11.14.000. Because of these great depths and the availability of ground water from shallower units, the Yeso Formation is not a major source of ground water in the county.

A sandstone unit in the Yeso Formation has been used as a disposal zone for uranium-mill effluent. Information from aquifer tests conducted at injection well 12.10.08.314 northeast of Bluewater indicates that the aquifer has a transmissivity of about 735 feet squared per day and a storage coefficient of about 6.2×10^{-4} (West, 1972, p. D1). Water-level and well-yield data are not available for the Yeso Formation.

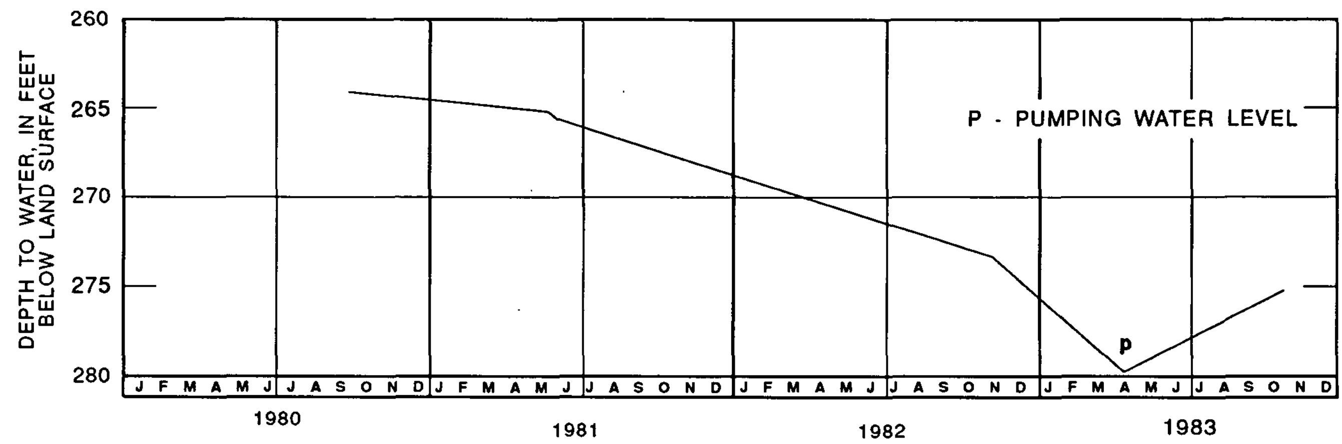


Figure 22.--Water levels in well 5.20.29.344 (site 62 in figures 16 and 17) in southwestern Cibola County, New Mexico.

Abo Formation

The Abo Formation is too deeply buried in Cibola County to be considered an important source of ground water. In the central part of the county at oil-test hole 06.11.14.000, Abo Formation strata were penetrated at a depth of 3,850 feet, and at oil-test hole 04.17.08.000, Abo strata were penetrated at a depth of 4,008 feet. Although the Abo Formation lies at relatively shallow depths along the eastern side of the county on the Lucero Uplift (1,435 feet at oil-test hole 07.04.26.000), the water probably is highly mineralized due to thick beds of anhydrite and gypsum. In the Grants-Bluewater area, on the northeastern flank of the Zuni Uplift, the Abo Formation was penetrated at a depth of 1,474 feet at well 12.10.08.314 (West, 1972, p. D10). The dissolved-solids concentration in a water sample collected from the Abo Formation at this well was 9,830 milligrams per liter (West, 1972, p. D13), indicating that the water is nonpotable. No information is available on aquifer characteristics, water levels, or well yields for the Abo Formation.

Precambrian Rocks

In the Zuni Mountains, ground water in the Precambrian rocks is present mainly in the upper 200 to 300 feet of weathered material and to a lesser extent in saturated faults or fracture zones. Below the zone of weathering, or in areas that are not faulted or fractured, the hydraulic conductivity of the rocks is very small and virtually no water is transmitted. Precambrian rocks probably are unsuitable for water supply outside the Zuni Mountain area because of the great depth of burial and small hydraulic conductivity.

SUMMARY

Rock units in Cibola County range in age from Precambrian to Quaternary. Not all units are exposed and some time intervals are not represented because of erosion or nondeposition. Structural features in the county include the Zuni Uplift, Gallup Embayment, Acoma Embayment, Rio Puerco fault zone, Lucero Uplift, and Mogollon Slope. Most rocks are sedimentary. Exceptions are the Precambrian igneous and metamorphic rocks exposed in the Zuni Uplift and basaltic rocks of Tertiary and Quaternary age in the northern and central parts of the county. Recharge areas, direction of ground-water movement, discharge areas, and water quality are influenced by these structural features.

Ground-water supplies in Cibola County are available in rocks ranging in age from Quaternary to Permian. Aquifers within the county include Quaternary alluvial deposits; basalts of Quaternary and Tertiary age; sandstone beds in the Mesaverde Group of Cretaceous age; Dakota-Zuni-Bluff aquifer, which includes rocks of Cretaceous and Jurassic age; Westwater Canyon aquifer and Todilto-Entrada aquifer; sandstone beds in the Triassic Chinle Formation; and San Andres-Glorieta aquifer.

Quaternary alluvium and alluvial-basalt sequences supply water to wells throughout the county. Wells as deep as 473 feet have been drilled in basalt and alluvium. Water quality in Quaternary material varies widely: dissolved-solids concentrations range from 200 to more than 5,900 milligrams per liter. The chemical composition of water from alluvial material also is quite variable. Predominant ions can include sodium, calcium, magnesium, bicarbonate, and sulfate. Well yields from alluvial material range from 5 to 1,110 gallons per minute.

Springs in the Mount Taylor area, on mesas near Grants, and near Paguate provide the only known source of water from Quaternary and Tertiary basalts in the county. Discharge rates as much as 2 gallons per minute were measured although discharge rates may be larger during snowmelt periods. Water-quality data show that water from springs in Quaternary and Tertiary basalts is a calcium magnesium type, containing dissolved-solids concentrations that range from 86 to 170 milligrams per liter.

Saturated sandstone beds in the Mesaverde Group yield sufficient volumes of water for stock and domestic purposes. The Mesaverde Group is present in the northeastern and along the southwestern parts of the county. Direct recharge from precipitation and from downward leakage supplies water to the aquifer. Potentiometric-surface maps could not be prepared due to the variation in head among the various sandstone beds. Ground-water flow systems in Mesaverde aquifers probably are local, with recharge occurring on topographically high areas and discharge occurring in adjacent topographically low areas. Water quality is variable, reflecting different geologic materials and residence times in the various sandstone beds. A trend from calcium bicarbonate water in outcrop areas to sodium bicarbonate water downgradient is evident in one small drainage basin. This trend probably represents ion exchange and may occur in other drainage basins where Mesaverde strata occur.

The Dakota-Zuni-Bluff aquifer is present throughout much of the county. The aquifer consists of three to four sandstone tongues of the Dakota Sandstone plus the Zuni and Bluff Sandstones and the Jackpile Sandstone Member of the Morrison Formation. The main bodies of the Dakota Sandstone and Zuni Sandstone probably are hydraulically connected, whereas the overlying Paguate and Twowells Sandstone Tongues are only slightly connected because the intertonguing Mancos Shale has small hydraulic conductivity. The Bluff Sandstone probably is in good hydraulic connection with only the Zuni Sandstone.

Water enters the aquifer on outcrop areas along the southern flanks of the Zuni Uplift; however, most ground water probably reaches the aquifer by downward leakage. Water moves westward in the western part of the county toward topographically lower areas. In the northeastern part of the county, water moves southeastward toward the Rio San Jose.

Information on water chemistry is available for the western part of the county. In this area, water in the Dakota-Zuni-Bluff aquifer is a sodium bicarbonate type where the aquifer is overlain by the main body of the Mancos Shale, whereas a calcium sulfate type water occurs where the Mancos has been removed by erosion. Dissolved-solids concentrations in water from 34 wells in the western part of the county range from 220 to 2,000 milligrams per liter.

Aquifers in Jurassic rocks include the Westwater Canyon aquifer and the Todilto-Entrada aquifer. These aquifers are present only in the northeastern part of the county because the Jurassic rocks were removed by erosion over much of the county. The Westwater Canyon aquifer includes the Westwater Canyon Member of the Morrison Formation and sandstones of the overlying Brushy Basin Member of the Morrison Formation. The aquifer is recharged by infiltration of precipitation on outcrop areas northeast of Grants and by leakage from overlying units. Ground water moves southeastward across the northeastern part of the county, discharging to the Rio Puerco and Rio San Jose Valleys. Transmissivity ranging from 4 to 490 feet squared per day has been reported for wells in the Westwater Canyon aquifer. Pumping rates range from 6 to 85 gallons per minute. Predominant ions in the aquifer include sodium, bicarbonate, and sulfate.

The Todilto-Entrada aquifer is recharged by infiltration of precipitation on outcrop areas south of the Rio San Jose and by leakage from overlying units. Water moves from the north and south toward the Rio San Jose to discharge to valley-fill material. Because of gypsum thicknesses of as much as 100 feet in the Todilto Formation, water in this aquifer is marginally suitable for stock use. Dissolved-solids concentrations range from about 700 to about 3,000 milligrams per liter.

The Chinle Formation of Triassic age occurs throughout much of the county and has thicknesses ranging from a feather edge to about 2,080 feet. Sandstone beds in the Petrified Forest Member of the Chinle Formation are important sources of water in the central and western parts of the county. The more productive areas of these sandstone beds may represent major river channels during Triassic time. The Correo Sandstone Bed of the Petrified Forest Member yields water to wells in the eastern part of the county. Recharge to the sandstone beds occurs on outcrop areas, possibly by upward leakage from the San Andres-Glorieta aquifer. Downward leakage from overlying sediments also may reach the sandstone beds. Data are not available to determine the direction of ground-water movement through the sandstone in the western part of the county. In the eastern part, ground water is believed to move toward the Rio San Jose through the Correo Sandstone Bed and westward away from the Lucero Uplift toward topographically low valley floors. Water from the Chinle Formation is typically a sodium bicarbonate type, containing dissolved-solids concentrations that range from 170 to 695 milligrams per liter in the western part of the county. Water chemistry is highly variable; water types range from sodium bicarbonate to calcium sulfate in the eastern part of the county. Dissolved-boron concentrations in water from some wells in the Chinle Formation exceed the U.S. Environmental Protection Agency recommended limit of 750 micrograms per liter. These anomalous boron concentrations seem to be associated with the Sonsela Sandstone Bed of the Petrified Forest Member in the western part of the county. No such correlation exists in the eastern part of the county. In general, dissolved-boron concentrations are greater in the eastern part of the county than in the western.

The San Andres-Glorieta aquifer of Permian age is present throughout most of the county and ranges in thickness from about 200 to about 720 feet. The aquifer is exposed around the uplifted margins of the Zuni Mountains and along the Lucero Uplift. The depth to the top of the aquifer ranges from about 1,000 to about 3,100 feet across much of the county. The aquifer is buried by as much as 8,300 feet of sedimentary and igneous rocks in the Mount Taylor area.

Recharge enters the aquifer along the flanks of the Zuni Mountains and moves downgradient through fractures and solution channels away from the recharge area. The hydraulic conductivity of the aquifer probably is small in the eastern part of the county because karst features may be more poorly developed there. A ground-water divide is believed to exist in the aquifer at roughly the same location as the Continental Divide. The regional discharge area for the western part of the aquifer is believed to be the valley of the Little Colorado River. The Ojo Caliente Monocline may serve as a barrier to westward-moving ground water in the northwestern part of the panhandle. About 450 gallons per minute of water discharge from the aquifer at Ojo Caliente Springs. Additional water may leak upward along the monocline and enter overlying units. Discharge areas for the eastern part of the aquifer include wells and springs in the Grants-Bluewater area and upward and downward leakage in the eastern part of the county.

Aquifer properties for the San Andres-Glorieta aquifer have been determined only in the Grants-Bluewater area where transmissivity ranges from 5.5×10^4 to 4.5×10^5 feet squared per day. Values of storage coefficient are 4.7×10^{-4} and 9.7×10^{-4} for observation wells 12.10.30.421 and 12.10.30.111, respectively. Well yields of as much as 2,830 gallons per minute have been reported from the San Andres-Glorieta aquifer in the Grants-Bluewater area.

The predominant ions in water from the aquifer generally are calcium, sulfate, and bicarbonate. Dissolved-solids concentrations in the aquifer appear to be greater in the eastern part of the county, possibly because of greater quantities of evaporite materials there.

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Table 1.--Approximate thickness, lithology, and water-yielding characteristics of rocks in the study area

Erathem	System	Stratigraphic unit	Hydrogeologic unit	Thickness (feet)	Lithology	Water-yielding characteristics
Cenozoic	Quaternary	Alluvium	Quaternary alluvium and alluvium-basalt sequences	0-200	Unconsolidated sands, silts, and gravels, present as channel-fill material or as blanket-type deposits	Well yields that range from 490 to 1,110 gallons per minute have been recorded from test holes along the Rio San Jose. Elsewhere in the county, wells commonly yield 5 to 10 gallons per minute
		Basalt		0-320	Basalt flow of North Plains, Rio San Jose Valley, and Fence Lake area	
		Spring deposits		Insufficient data	Insufficient data	
		Landslides		Insufficient data		Insufficient data
Cenozoic	Quaternary and Tertiary	Basalt, undifferentiated	Quaternary and Tertiary basalts	0-1,000	Basalt flows of Cebolleta Mesa, Mesa del Oro, La Jara Mesa, Horace Mesa, and Mesa Chivato	Springs along the margins of Horace and La Jara Mesas provide water for stock and domestic use
		Mount Taylor volcanics		0-3,000	Basalts interbedded with mudflows, volcaniclastic debris, dikes, and pyroclastic flow material	Numerous springs discharge as much as 2 gallons per minute; discharge is greater than 2 gallons per minute during snowmelt periods
		Igneous, intrusive		Insufficient data	Intrusive dikes, sills, and plugs	These rocks have little or no water-yielding capability

Table 1.--Approximate thickness, lithology, and water-yielding characteristics of rocks in the study area--Continued

Erathem	System	Stratigraphic unit	Hydrologic unit	Thickness (feet)	Lithology	Water-yielding characteristics
Cenozoic	Tertiary	Fence Lake Formation	No associated hydrologic units	0-200	Unconsolidated fluvial and lacustrine sands and gravels capping mesas and plateaus	Material is believed to be unsaturated throughout the area of occurrence in the county
		Spears Formation		200-300?	Interbedded claystones and volcanic wackes	
Mesozoic	Cretaceous	Mesaverde Group: Point Lookout Sandstone	Sandstones in the Mesaverde Group	Insufficient data	Insufficient data	Insufficient data
		Mesaverde Group: Crevasse Canyon Formation: Gibson Coal Member; Dalton Sandstone Member; Dilco Coal Member		100-1,000	Marine and nonmarine sandstone, mudstone, and shale	Water generally is suitable for most uses
		Gallup Sandstone		0-400	Marine and nonmarine sandstones, carbonaceous mudstones, and thin coal beds	Insufficient data

Table 1.--Approximate thickness, lithology, and water-yielding characteristics of rocks in the study area--Continued

Erathem	System	Stratigraphic unit		Hydrologic unit	Thickness (feet)	Lithology	Water-yielding characteristics
Mesozoic	Cretaceous	Mancos Shale	Mulatto Tongue	No associated hydrogeologic unit	225-385	Dark-gray calcareous marine shale	Small-permeability confining unit. Yields to wells are unknown
		Tres Hermanos Sandstone					
		Dakota Sandstone	Twowells Tongue Member	Dakota-Zuni-Bluff aquifer	0-310 east, 0-140 west	Marine, marginal marine, and nonmarine silty sandstone. Individual sandstone tongues have a maximum thickness of 90 feet	Yields of 30 gallons per minute to wells are reported from the Dakota-Zuni-Bluff aquifer in the western part of the county
			Paguate Tongue Member				
			Cubero Tongue Member				
			Oak Canyon Member				
Mesozoic	Jurassic	Morrison Formation	Jackpile Sandstone Member	Dakota-Zuni-Bluff aquifer	315-620	Fluvial, flood-plain channel deposits. Upper and lower members have a high proportion of clay and mudstone. Middle member is fine- to medium-grained sandstone	Yields of as much as 100 gallons per minute to industrial wells are reported from the Westwater Canyon aquifer in the northeastern part of the county
			Brushy Basin Member	Westwater Canyon aquifer			
			Westwater Canyon Member				
			Recapture Member	No associated hydrogeologic unit			
		Zuni Sandstone		Dakota-Zuni-Bluff aquifer	0-500	Fine-grained, massive, crossbedded, eolian sandstone	Included in the Dakota-Zuni-Bluff aquifer

Table 1.--Approximate thickness, lithology, and water-yielding characteristics of rocks in the study area--Continued

Erathem	System	Group	Stratigraphic unit		Hydrologic unit	Thickness (feet)	Lithology	Water-yielding characteristics
Mesozoic	Jurassic	San Rafael Group	Bluff Sandstone		Dakota-Zuni-Bluff aquifer	0-400	Fine- to medium-grained fluvial and eolian sandstone	Insufficient data
Mesozoic	Jurassic	San Rafael Group	Summerville Formation		No associated hydrogeologic unit	0-200	Fine-grained intertidal sandstone and silty mudstone	Small-permeability confining unit
Mesozoic	Jurassic	San Rafael Group	Todilto Limestone		Todilto-Entrada aquifer	10-110	Thin, persistent limestone overlain by locally thick gypsum and anhydrite	Todilto-Entrada aquifer yields 1 to 3 gallons per minute to wells in northeastern part of county
Mesozoic	Jurassic	San Rafael Group	Entrada Sandstone	Upper sandstone facies	Todilto-Entrada aquifer	0-350	Fluvial sandstone, intertidal siltstone	Todilto-Entrada aquifer yields 1 to 3 gallons per minute to wells in northeastern part of county
Mesozoic	Jurassic	San Rafael Group	Entrada Sandstone	Middle siltstone facies	Todilto-Entrada aquifer	0-350	Fluvial sandstone, intertidal siltstone	Todilto-Entrada aquifer yields 1 to 3 gallons per minute to wells in northeastern part of county
Mesozoic	Jurassic	San Rafael Group	Entrada Sandstone	Lower sandstone facies	Todilto-Entrada aquifer	0-350	Fluvial sandstone, intertidal siltstone	Todilto-Entrada aquifer yields 1 to 3 gallons per minute to wells in northeastern part of county
Mesozoic	Triassic		Wingate Sandstone	Rock Point Member		80-325	Fluvial siltstone, mudstone, sandstone, bedded channel sandstones. Some limestone in the upper part of the Chinle Formation	Sandstones within the Wingate Sandstone may yield water locally

Table 1.--Approximate thickness, lithology, and water-yielding characteristics of rocks in the study area--Continued

Erathem	System	Stratigraphic unit			Hydrologic unit	Thickness (feet)	Lithology	Water-yielding characteristics
Mesozoic	Triassic	Chinle Formation (includes Moenkopi formation)	Petrified Forest Member	Correo Sandstone Bed	Sandstone beds in the Chinle Formation	0-2,080	Fluvial siltstone, mudstone, sandstone, bedded channel sandstones. Some limestone in the upper part of the Chinle Formation	Sandstones in the Chinle Formation yield from 0.5 to 6 gallons per minute to stock wells. Chinle sandstones in the western part of county are more productive than in the eastern part of the county
				Sonsela Sandstone Bed				
				Lower mudstone bed				
			Monitor Butte Member					
Paleozoic	Permian	San Andres Limestone			San Andres-Glorieta aquifer	0-450	Marine fossiliferous limestone with some interbedded sandstone. Thick gypsum beds in eastern part of county	Yields as much as 2,830 gallons per minute to wells in Grants-Bluewater area from the San Andres-Glorieta aquifer. Springs in Grants-Bluewater area yield as much as 450 gallons per minute. Wells in Ojo Caliente area discharge as much as 450 gallons per minute. Stock wells in other areas of county yield 5 gallons per minute. Wells in Ojo Caliente area discharge as much as 450 gallons per minute
		Glorieta Sandstone				0-300	Massive-bedded, fine- to medium-grained, well-cemented intertidal sandstone	

Table 1.--Approximate thickness, lithology, and water-yielding characteristics of rocks in the study area--Concluded

Erathem	System	Stratigraphic unit		Hydrologic unit	Thickness (feet)	Lithology	Water-yielding characteristics
Paleozoic	Permian	Yeso Formation	San Ysidro Member	No associated hydrogeologic units	0-1,400	Gypsiferous shale, siltstone, silty sandstone, with some thin-bedded limestone	
			Meseta Blanca Sandstone Member				
		Abo Formation			300-1,200	Reddish-brown sandstone and siltstone with some conglomerate in lower part	
Paleozoic	Pennsylvanian	Undifferentiated rocks		No associated hydrogeologic units	0-2,000	Conglomerate, arkose, shale, and limestone	Insufficient data
		Precambrian			Insufficient data	Granite, gneiss, metarhyolite, schist, and quartzite	Locally yields water from upper weathered zone and faults in the Zuni Mountains; one well yields 3 gallons per minute; one spring discharges 6 gallons per minute

[1]Since this report was prepared, the Summerville Formation is geographically restricted from the area and the rocks are assigned to the Wanakah Formation. The Todilto Formation is reduced in rank and is the basal Todilto Limestone Member of the Wanakah Formation (Condon and Huffman, 1988, figs. A2 and A3). The Bluff Sandstone is reduced in rank, and where present is the basal Bluff Sandstone Member of the Morrison Formation. The Bluff is geographically restricted from New Mexico and the rocks are assigned to other members of the Morrison Formation (Peterson, 1988, fig. B18).

Table 2.--Records of wells and springs in Cibola County

EXPLANATION

Well or spring number: Wells and springs in this table are located to the nearest 10-acre plot as described in the text. All wells and springs are located north of the New Mexico Base Line and west of the New Mexico Principal Meridian.

Owner: Geographical or place names or names of owners are tabulated in most cases to aid in well or spring identification.

Geologic unit: 110AVMB, alluvium; 111MCCR, McCartys Basalt; 122FCLK, Fence Lake Formation; 122SPRS, Spears Formation (Chapin, 1971); 211MVRD, Mesaverde Group; 211PNLK, Point Lookout Sandstone; 211CRVC, Crevasse Canyon Formation; 211GLLP, Gallup Sandstone; 211DKOT, Dakota Sandstone; 221ZUNI, Zuni Sandstone; 224ENRD, Entrada Sandstone; 221MRSN, Morrison Formation; 221BRSB, Brushy Basin Member of Morrison Formation; 221WSRC, Westwater Canyon Member of Morrison Formation; 231RCKP, Rock Point Member of Wingate Sandstone; 231CHNL, Chinle Formation; 231SNSL, Sonsela Sandstone Bed of Petrified Forest Member of Chinle Formation; 313SADG, San Andres Limestone and Glorieta Sandstone; 313SADY, San Andres Limestone and Yeso Formation; 318YESO, Yeso Formation; 319ABO, Abo Formation; 400PCMB, Precambrian; 000EXRV, Extrusive rocks.

Use of water: U, unused; S, stock; H, domestic; D, dry; P, public supply; I, irrigation; R, recreation; N, industrial; T, institution.

Altitude of land surface: The altitude of land surface, in feet above sea level, is obtained from U.S. Geological Survey 7 1/2-minute topographic maps.

Other abbreviations: R, reported; UTM, unable to measure; DST, drill-stem test; dry, material unsaturated at indicated well depth; --, no data.

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
04.06.12.111		Major, Buddy	231CHNL	1,130	12.75	07-08-70	U	Flowing	05-02-84	6,070
04.07.04.433		Red Lake Ranch	211DKOT	140	--	--	S	81.98	05-21-81	6,630
04.07.07.111		Red Lake Ranch	211MVRD	298	6	--	S	238.76	05-14-81	6,744
04.08.07.433		Major, Buddy	211DKOT	--	5.60	--	U	--	--	7,985
04.09.01.341		Major, Buddy	211DKOT	--	6.37	--	S	--	--	7,588
04.09.01.424		Major, Buddy	211DKOT	79	--	--	U	75.10	03-17-81	7,580
04.09.09.131		Major, Buddy	211CRVC	--	9.10	--	S	51.08	03-02-81	7,719
04.10.08.313		King Bros.	211CRVC	--	5.20	- -51	S	52.60	05-05-81	7,552
04.11.05.112		King Bros.	211CRVC	178	6.50	--	S	105.83	04-27-81	7,185
04.11.06.111		King Bros.	211CRVC	271	5.60	- -63	S	214.10	04-27-81	7,346
04.11.08.124A		King Bros.	211CRVC	154	6.70	--	S	71.65	04-28-81	7,200
04.11.08.124B		King Bros.	110AVMB	80	5.50	--	U	72.95	04-28-81	7,200
04.11.11.213		King Bros.	211GLLP	221	--	- -43	S	149.30	05-05-81	7,336
04.11.12.432		King Bros.	211CRVC	56	6.50	--	S,H	28.40	04-29-81	7,410
04.12.02.133		King Bros.	121LGUN	96	6.40	--	S	65.00	04-27-81	7,128
04.12.11.342		King Bros.	211CRVC	166	5.25	--	S	85.30	04-28-81	7,198
04.14.10.211		Hubbell, Frank	211DKOT	--	--	- -24	S	--	--	7,340
04.15.04.423		Cox, Claude	122SPRS	--	--	--	U	--	--	7,630
04.16.03.321		--	211MVRD	--	--	09-12-79	U	136R	09-12-79	6,980
04.16.04.241		Brown, J.C.	211MVRD	--	6.84	--	S	279.32	12-17-80	6,970
04.16.07.212		Montaño Bros.	211MVRD	230R	6.63	04- -71	S	184.86	02-11-81	6,870
04.16.07.223		Montaño Bros.	211MVRD	80R	--	10-16-79	U	--	10-16-79	6,850
04.16.07.421		Montaño Bros.	211MVRD	--	6.63	08- -80	S	82.58	02-11-81	6,840
04.16.07.434		Montaño Bros.	211MVRD	244R	--	05-14-80	U	83R	05-14-80	6,845
04.16.10.131		Williamson, Tom	211MVRD	272R	--	09-08-79	U	143R	09-08-79	6,920
04.16.10.331A		Williamson, Tom	211MVRD	280R	6.80	--	S,H	141.17	12-17-80	6,860
04.16.10.331B		Williamson, Tom	211MVRD	230R	8.1	--	S	--	--	6,840
04.16.11.332		Williamson, Tom	211MVRD	--	--	--	S	154.34	12-17-80	6,894
04.17.03.312		Green, Bill	211MVRD	250R	--	05-20-80	U	227R	05-20-80	6,880
04.17.03.324A		Green, Bill	211MVRD	--	--	--	S	100.32	10-13-80	6,820

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
04.17.03.324B		Green, Bill	211MVRD	--	--	--	--	117.00	10-13-80	6,820
04.17.04.233		Bell, Merl	211MVRD	--	--	--	S	--	--	6,806
04.17.08.121		Cox, Bert	211MVRD	252R	--	--	S	189.90	10-14-80	6,846
04.17.10.211		Cox, Bert	211MVRD	435	--	--	S	--	--	6,797
04.18.05.144A		Cox, Bert	211MVRD	320	4.50	--	S	192.05	10-31-80	7,339
04.18.05.144B		Cox, Bert	211MVRD	320	6.60	--	S	164.24	10-31-80	7,339
04.18.05.212		Dodson	211CRVC	--	5	--	S	133.79	10-08-80	7,315
05.04.05.142	89	Dockery	313SADG	630	--	--	S	580.00	06-09-80	6,610
05.04.26.411		Yriart, Juan	319ABO	150	--	--	S	66.62	02-05-57	6,063
05.05.10.333A	90	Seis, Wally	231CHNL	--	--	--	S	--	--	6,358
05.05.10.333B	91	Seis, Wally	231CHNL	251	16.25	--	S	139.99	06-09-81	6,358
05.05.16.443	92	Seis, Wally	231CHNL	78	5.60	--	S	76.28	06-09-81	6,280
05.06.25.122		Seis-Wilson	231CHNL	453	7.0	06-24-61	S	270R	06-24-61	6,780
05.06.31.242	93	Seis, Wally	231CHNL	155	7.08	--	S	147.29	06-10-81	7,025
05.07.29.122		Red Lake Ranch	211MVRD	247	8.70	--	U	210.48	05-14-81	6,935
05.07.34.433		Red Lake Ranch	000EXRV	--	--	--	S,D	--	--	7,000
05.07.35.334		Red Lake Ranch	211DKOT	221	6.72	--	S	164.00	05-21-81	6,165
05.08.01.114		Red Lake Ranch	211DKOT	27	7.07	--	U	22.46	05-21-81	7,234
05.08.04.212		Red Lake Ranch	211DKOT	186	6.70	--	S	32.33	05-21-81	7,270
05.08.08.234		Red Lake Ranch	211DKOT	--	10.70	--	U	26.60	03-03-81	7,304
05.08.11.214		Red Lake Ranch	211DKOT	146	6.72	--	S	--	--	7,270
05.08.18.421		Red Lake Ranch	211GLLP	110	10.80	--	U	50.74	05-21-81	7,414
05.08.21.423		Red Lake Ranch	211DKOT	350	5.60	--	U	250.90	05-31-81	7,366
05.08.32.111		Red Lake Ranch	211DKOT	103	6.25	--	S	36.88	05-12-81	7,430
05.08.35.123		Red Lake Ranch	313SADG	2,019	6.62	10-27-86	U	552.8	12-14-86	6,977
05.08.36.433A		Red Lake Ranch	231CHNL	163	6.70	--	U	115.85	05-12-81	6,830
05.08.36.433B		Red Lake Ranch	231CHNL	150	7	--	U	109.69	05-12-81	6,830
05.09.03.133		Major, Buddy	211DKOT	43R	5.16	--	U	42.10	03-18-81	7,595
05.09.10.131		Major, Buddy	211DKOT	67	6.70	--	S	31.44	03-18-81	7,670
05.09.14.221		Major, Buddy	211DKOT	--	5.72	--	U	30.84	03-26-81	7,475
05.09.19.433		Major, Buddy	211CRVC	31	6	--	U	21.95	03-18-81	7,700
05.09.26.412		Major, Buddy	211GLLP	201	--	--	S	160.75	03-18-81	7,634
05.09.31.323A		Major, Buddy	211CRVC	181	6.70	--	U	68.36	03-18-81	7,735
05.09.31.323B		Major, Buddy	211CRVC	--	--	--	--	--	--	--
05.10.12.113		King Bros.	211GLLP	Spring	--	--	S	--	--	7,415

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
05.10.12.141		King Bros.	211GLLP	Spring	--	--	S	--	--	7,420
05.10.17.412		King Bros.	211CRVC	253	5.50	--	S	149.91	05-05-81	7,860
05.10.23.422		King Bros.	211CRVC	--	--	--	S	19.01	05-05-81	7,503
05.10.27.233		King Bros.	211CRVC	130	5.40	--	S	43.66	05-05-81	7,560
05.10.35.223		King Bros.	211CRVC	--	--	--	S	--	--	7,582
05.11.15.242		King Bros.	211MVRD	--	6	--	S	113.10	10-05-78	7,243
05.11.26.323		King Bros.	211GLLP	380	6.90	09-06-78	S	283.35	05-05-81	7,300
05.12.01.224		King Bros.	211CRVC	230	5.90	--	S	181.36	04-28-81	7,110
05.12.04.112	28	King Bros.	211DKOT	500	5.70	- -55	S	283.50	04-27-81	7,174
05.12.13.141	29	King Bros.	211DKOT	--	6	- -00	S	226R	- -78	7,094
05.12.20.133		King Bros.	211GLLP	--	--	--	S	92.70	04-27-81	7,179
05.12.25.344		King Bros.	211MVRD	215R	--	--	S	--	--	7,114
05.12.27.313		King Bros.	211GLLP	250R	5.50	--	S	175.85	04-27-81	7,164
05.13.15.333		Hubbell, Frank	211GLLP	--	6.50	--	S	--	--	7,232
05.13.18.113		Hubbell, Frank	211MVRD	--	--	--	S	223.40	11-28-78	7,247
05.14.06.334		Green, Fletcher	211MVRD	--	6.84	--	S	327.22	12-18-80	7,397
05.14.15.334	30	Hubbell, Frank	211DKOT	--	--	--	S	--	--	7,845
05.15.16.223	31	Hubbell, Frank	211DKOT	381	6.20	- -28	S	350R	--	7,365
05.15.19.444		Towner, Herman	211MVRD	100	6.68	--	S	87R	12-04-80	7,332
05.15.24.113		Smith, Lindel	211MVRD	362	6.75	--	U	329.78	12-18-80	7,405
05.15.26.133		Cox, Claude	211MVRD	--	5.70	--	S,H	336.43	12-26-80	7,392
05.15.28.431		Cox, Claude	211MVRD	--	6.84	--	S	261.00	12-16-80	7,490
05.15.31.222A		Towner, Herman	211MVRD	710	--	--	H	320.00	--	7,425
05.15.31.222B		Towner, Herman	211MVRD	--	6.75	--	U	406.66	12-04-80	7,422
05.16.19.141	32	Dye, Bedford	211DKOT	430R	--	--	H,S	--	--	7,298
05.16.19.343		Dye, Bedford	--	250	--	- -79	D	Dry	- -79	7,220
05.16.21.242	33	Cox, Bert	211DKOT	800R	8	--	S	--	--	7,308
05.16.22.213		Cosby, Kenneth	--	254	--	79	D	Dry	- -79	7,310
05.16.23.411		Hubbell, Frank	211DKOT	900R	5.63	09- -80	S	503.64	07-16-81	7,330
05.16.25.121		Towner, Earl	211MVRD	300R	6.87	--	S	248.00	12-04-80	7,365

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
05.16.30.321		Hall, W.	--	250	--	- -79	D	Dry	- -79	7,300
05.16.31.413		Montaño Bros.	--	253	--	- -79	D	Dry	- -79	7,020
05.16.31.441		Montaño Bros.	211GLLP	300R	--	--	S	57.26	02-11-81	6,980
05.16.36.431		--	211MVRD	Spring	--	--	S	--	--	7,200
05.17.01.141		Allen, Charlie	211MVRD	294	6.60	--	U	257.09	11-20-80	7,200
05.17.02.114		Allen, Charlie	211MVRD	--	4.60	--	U	121.70	11-20-80	7,059
05.17.03.221		Allen, Charlie	211MVRD	108	5.10	--	U	86.51	11-20-80	7,020
05.17.03.231		Allen, Charlie	211MVRD	96	5	--	U	71.53	11-20-80	7,005
05.17.05.232	11	Monday	211MVRD	200	--	--	H	--	--	6,972
05.17.05.444	12	Bruton, Doug	211MVRD	420	7.0	--	S	134.08	11-13-80	6,952
05.17.06.333	13	Alred	211MVRD	184	--	--	S	--	--	6,954
05.17.07.333	14	McDuff	211MVRD	225R	--	--	S	--	--	7,000
05.17.09.223	15	Jacobe	211MVRD	--	--	--	S	--	--	6,982
05.17.10.344	16	Bogart, H.L.	211MVRD	505	6.62	10-05-71	S	112.50	11-19-80	7,025
05.17.13.132A	34	Hall, W.T.	211DKOT	700	--	--	H	--	--	7,121
05.17.13.132B		Hall, W.T.	--	516	--	- -79	D	Dry	- -79	7,120
05.17.14.443	35	Brown, J.C.	211DKOT	750	--	--	S,H	--	--	7,128
05.17.15.324A		Brown, J.C.	211MVRD	232	--	--	U	--	--	7,060
05.17.15.324B		Brown, J.C.	211MVRD	234	--	- -79	U	232R	- -79	7,060
05.17.24.324		Bell, Merl C.	--	250	--	- -79	U	Dry	- -79	7,225
05.17.25.224		Hall, W.T.	--	250	--	- -79	D	Dry	- -79	7,250
05.17.25.411		Hall, W.T.	--	250	--	- -79	D	Dry	- -79	7,340
05.17.27.221		Bell, Merl C.	--	250	--	- -79	D	Dry	- -79	7,150
05.17.27.231		Wilson, Ethan	--	526	--	- -79	D	Dry	- -79	7,150
05.17.27.311		Bell, Merl C.	--	250	--	- -79	D	Dry	- -79	7,150
05.17.29.131		Bell, Merl C.	211MVRD	365	--	--	H	--	--	7,055
05.17.31.211		Cox, Bert	211MVRD	425	6	--	S	--	--	6,968
05.17.34.133		Bell, Merl C.	--	250	--	- -79	D	Dry	- -79	6,910
05.18.01.233	17	Boyett, Ray	211MVRD	275	6.50	--	S	225.00	10-04-80	6,922
05.18.08.223	18	Yates, John	211MVRD	--	6	--	S	191.48	11-12-80	6,974

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
05.18.10.342	19	Boyett, Ray	211MVRD	300	6.38	05-12-67	S	--	--	7,035
05.18.12.212	20	Boyett, Ray	211MVRD	170	--	--	H	--	--	6,972
05.18.13.222	21	Bruton, Doug	211MVRD	180R	7	--	H	UTM	--	7,008
05.18.13.444	36	Peralta, James	211DKOT	600	--	--	H	--	--	7,075
05.18.15.111	22	Bogart, H.	211MVRD	300	--	--	S,H	275.00	12-02-80	7,044
05.18.15.444	23	Bogart	211MVRD	200	--	--	S	175.00	12-02-80	7,070
05.18.23.233		Thomas, Lonnie	211MVRD	350	8	--	S	210R	01-05-81	7,108
05.18.24.324	24	Bogart, Kathleen	211MVRD	255	6.62	04-26-70	S	--	--	7,105
05.18.25.224		Bogart, Kathleen	211MVRD	--	4	--	U	174.30	04-10-80	7,125
05.18.26.241		Cox, Bert	211MVRD	220	4.90	--	U	102.75	12-18-80	7,150
05.18.27.222		Lancaster, Ron	122FCLK	--	5.72	--	H	42.79	01-06-81	7,192
05.18.28.122		Thomas, A.L.	211MVRD	400	6.62	06-12-74	H	310R	06-12-74	7,420
05.19.04.111		Yates, John	211MVRD	167	5	--	U	153.48	11-19-80	6,560
05.19.04.444A		Yates, John	211DKOT	200	--	--	U	144.80	11-12-80	6,629
05.19.04.444B	37	Yates, John	211DKOT	--	--	--	S	--	--	6,629
05.19.07.334		Cook, Len	211MVRD	Spring	--	--	--	--	--	6,970
05.19.29.213		Cox, Bert	211MVRD	--	6.50	--	S	94.32	11-19-80	7,205
05.20.02.214		Cook, Len	211DKOT	600R	6	--	S	393.93	10-14-80	6,650
05.20.05.443		Cook, Len	122FCLK	340	6	--	U	Dry	10-22-80	6,840
05.20.14.242		Cook, Len	211CRVC	--	6	--	S	140.83	09-26-80	7,185
05.20.24.122		Hinkson, Everett	211CRVC	180	6	04- -57	S	112.97	09-24-80	7,126
05.20.29.344	62	Hinkson, Everett	313SADG	1,453	5.50	05-08-50	S	264.44	09-24-80	6,527
05.21.10.112A		Hinkson, Everett	211DKOT	208	6	07- -75	S,H	99.73	09-24-80	6,600
05.21.10.112B	38	Hinkson, Everett	211DKOT	300	--	--	S,H	125.00	09- -75	6,600
05.21.35.321	63	Hinkson, Everett	313SADG	1,300	6	- -75	S	100R	- -75	6,236
06.04.02.221		Seis, Wally	231CHNL	175	5.80	--	U	153.54	05-19-81	6,220
06.05.26.132	94	Seis-Wilson	313SADG	623	--	--	S	620R	10-12-53	6,370
06.08.34.333A		Major, Buddy	211DKOT	106	6.70	--	U	15.04	05-21-81	7,255
06.08.34.333B		Major, Buddy	211DKOT	65	19.20	--	U	14.32	05-21-81	7,255
06.08.34.341		Major, Buddy	110AVMB	34	10.80	--	U	16.15	05-21-81	7,260

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
06.10.06.121	39	King Bros.	221ZUNI	336	6.40	--	S	233.82	04-30-81	7,095
06.10.07.141		USBLM	313SADG	2,783	6.62	11-17-86	U	711.0	11-17-86	7,130
06.10.07.232	40	King Bros.	211DKOT	230	--	--	S	125.69	04-30-81	7,134
06.10.20.114	41	King Bros.	211DKOT	130R	6.75	--	S	124.65	10-06-78	7,210
06.10.20.411		King Bros.	110AVMB	84R	6.15	--	S	52.77	10-06-78	7,200
06.11.02.412		King Bros.	211DKOT	500	--	- -60	S	55.14	04-30-81	7,144
06.11.34.113		King Bros.	110AVMB	50R	36	--	S	46.08	10-05-78	7,070
06.11.34.322		King Bros.	211MVRD	143	6	- -39	S	99.91	05-27-56	7,080
06.12.01.311	42	King Bros.	221ZUNI	330	--	- -57	S	325R	--	7,100
06.12.13.421	43	King Bros.	211DKOT	220	--	--	S	182.40	04-27-78	7,081
06.13.17.112		Moleras, W.	211DKOT	450	--	- -38	--	350.00	- -71	7,380
06.14.14.111		Ramah Navajos	211DKOT	650	6.6	- -59	S	393.00	- -71	7,472
06.16.32.222		Hubbell, Frank	211MVRD	228	--	--	S	--	--	7,170
06.17.02.342		Dearmond, M.	211DKOT	128	5	- -00	S	124.78	04-21-80	7,010
06.17.05.411		Bruton, Doug	211DKOT	405	6.62	--	S	375R	07-07-71	6,950
06.17.13.342		Jackson	211DKOT	--	8.30	--	S	164.86	01-06-81	7,108
06.17.16.331		Jackson	211DKOT	--	6.76	--	S	135.76	11-13-80	7,028
06.17.18.233		Lola	110AVMB	--	5.50	--	U	17.99	04-10-80	6,810
06.17.18.321		Lola	110AVMB	--	--	--	H	26.55	10-31-80	6,815
06.17.19.131	44	McDonald, Dave	211DKOT	323R	5.0	--	H	180R	11-14-80	6,930
06.17.20.442		Jackson	211DKOT	--	5.60	--	S	--	--	6,990
06.17.22.421		White	211MVRD	160R	--	--	H	40R	01-06-81	7,000
06.17.27.123	25	Jackson	211MVRD	--	--	--	S	146R	01-06-81	6,952
06.17.30.111		Schultz	211DKOT	240R	--	--	H	--	--	6,927
06.17.30.214		Jackson	211DKOT	--	6.70	--	S	--	--	6,955
06.17.30.311		Allen, Gilbert	211DKOT	162R	--	--	H	--	--	6,960
06.17.31.313	26	Allen, Charlie	211MVRD	--	5.90	--	H	110.48	11-20-80	6,950
06.17.33.212		Odell, Richard	110AVMB	10R	--	--	H,S	--	--	7,196
06.17.34.433A		Bruton, Doug	211MVRD	70R	4.80	--	U	50.78	11-30-80	6,988
06.17.34.433B	27	Bruton, Doug	211MVRD	86	--	--	S	50.96	11-13-80	6,890

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
06.17.35.333		Allen, Charlie	211MVRD	160	5.00	--	U	110.78	11-20-80	7,052
06.18.10.232	73	Yates, John	231CHNL	--	--	--	S	--	--	6,901
06.18.23.124		Yates, John	231CHNL	128	4.50	--	U	49.28	11-12-80	6,800
06.18.27.433		Yates, John	000EXRV	--	--	--	S	--	--	6,907
06.18.30.214		Yates, John	211MVRD	Spring	--	--	S	--	--	6,620
06.19.01.131	74	Yates, John	231CHNL	400R	--	--	S	--	--	6,771
06.19.13.413	75	Yates, John	231CHNL	--	--	--	S	--	--	6,738
06.19.16.113	45	Yates, John	211DKOT	--	--	--	S	--	--	6,609
06.19.24.311		Yates, John	211DKOT	40R	--	--	S	--	--	6,521
06.19.24.421	46	Yates, John	211DKOT	90R	--	--	S	--	--	6,674
06.19.29.231	47	Yates, John	211DKOT	252R	--	--	S	--	--	6,490
06.19.30.233		Yates, John	211DKOT	--	6	--	S	98.88	11-11-81	6,535
06.20.04.233	48	Hinkson, Everett	211DKOT	--	6	--	S	--	--	6,250
06.20.06.444		Hinkson, Everett	211DKOT	307	6	--	S	88.52	09-25-80	6,324
06.20.10.213		Hinkson, Everett	211DKOT	--	6	--	S	93.37	10-01-80	6,274
06.20.10.442		Cook, Len	211DKOT	--	6	--	S	84.22	10-21-80	6,293
06.20.14.412		Cook, Len	211DKOT	200R	6	--	S	128.44	10-02-80	6,360
06.20.31.132		Cook, Len	211DKOT	355	6	--	U	338.00	10-22-80	6,762
06.21.10.222		Hinkson, Everett	211DKOT	270R	6	09-22-47	S	150.68	09-30-80	6,358
07.04.02.344		Major, Buddy	110AVMB	42	7.30	--	U	31.03	05-19-81	5,795
07.04.06.342		Harrington	110AVMB	60R	6	--	S	37.40	11-02-73	5,738
07.04.11.431		Major, Buddy	231CHNL	Spring	--	--	S	--	--	5,850
07.04.13.114	95	Major, Buddy	110AVMB	107	6.12	--	S	85.67	05-19-81	5,850
07.04.15.222	96	Major, Buddy	110AVMB	44	7.30	--	S	39.12	05-19-81	5,826
07.04.22.323		Seis, Wally	231CHNL	300	6.63	--	U	272.00	06-09-81	5,938
07.04.25.111	97	Major, Buddy	313SADG	150	7.10	--	S	125.82	05-19-81	5,981
07.04.29.421	98	Seis, Wally	110AVMB	--	4.54	--	S	130.35	06-09-81	6,155
07.05.01.133		Seis-Wilson	110AVMB	165	--	--	S	153.20	10-05-73	5,677
07.05.06.221A	99	Marmon, Fred	231CHNL	--	--	--	S	--	--	5,757
07.05.06.221B		Marmon, Fred	231CHNL	61	4		S	55.36	08-31-73	5,757

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
07.05.10.212		Wilson, Carl	110AVMB	101	6.63	04- -71	S	54.08	10-05-73	5,693
07.05.18.224		Seis-Wilson	110AVMB	103	--	--	S	90.73	10-05-73	5,761
07.05.36.333	100	Seis, Wally	231CHNL	--	6.53	--	S	--	--	6,125
07.06.10.443A		Marmon, Fred	231CHNL	74	6.23	--	H	70.21	03-19-81	5,852
07.06.10.443B	101	Marmon, Fred	231CHNL	75	5.53	--	S	71.50	03-19-81	5,852
07.06.18.424	102	Marmon, Fred	231CHNL	--	6.23	--	S	47.87	03-19-81	5,940
07.06.19.222		Rivera	110AVMB	86R	--	--	S	--	--	5,946
07.06.20.314		Rivera	110AVMB	77	--	--	S	52.15	10-05-73	5,959
07.06.22.331	103	Marmon, Fred	231CHNL	96	6.23	--	S	92.99	03-19-81	5,822
07.06.26.212		Seis-Wilson	110AVMB	23	6	--	S	8.90	10-05-73	5,782
07.06.30.222		Daily	110AVMB	68	6	--	S	58.01	10-05-73	5,968
07.06.34.432		Seis-Wilson	110AVMB	--	--	--	S	--	--	5,826
07.09.09.334		King Bros.	211MVRD	Spring	--	--	--	--	--	7,520
07.10.20.414A		King Bros.	221ZUNI	117	6	--	S	100.90	05-27-56	7,070
07.10.20.414B		King Bros.	221ZUNI	120	6.20	- -65	S	104.87	04-30-81	7,065
07.10.22.112		King Bros.	221ZUNI	263	8.80	- -69	S	--	--	7,240
07.11.02.311	64	King Bros.	313SADG	420	--	--	S	--	--	7,070
07.12.13.244	65	King Bros.	313SADG	1,000	--	12- -38	S	689.60	08-02-84	7,200
07.12.21.433		King Bros.	221ZUNI	500	5.40	--	S	461.70	04-28-81	7,200
07.14.22.214		Ramah Navajos	211GLLP	536	6	- -35	S,H	434.00	- -71	7,595
07.15.12.400		Martinez, Juan	211DKOT	790R	6.63	08-01-73	S	350R	08-01-73	7,500
07.15.19.244		Ramah Navajos	211GLLP	530	6.63	09-17-35	S	289.00	--	7,370
07.15.23.223		Ramah Navajos	211DKOT	700	6.0	- -57	S	345.00	07-14-69	7,453
07.16.06.314	49	Griego, Pablo	211DKOT	--	--	- -80	S,H	--	--	7,090
07.16.10.111		Ramah Navajos	211GLLP	460	--	- -58	--	207.00	- -71	7,300
07.16.21.342		Ramah Navajos	211GLLP	589	8	- -53	S	211.00	- -71	7,200
07.17.11.244		Arnold, F.	211DKOT	650	--	- -71	--	250.00	- -71	7,050
07.17.11.244		Arnold, Frank	211DKOT	650	6.62	--	H	450.00	--	7,005
07.17.16.214	50	Yates, John	211DKOT	--	--	--	S	--	--	6,930
07.17.30.121	76	Yates, John	231CHNL	--	--	--	S	--	--	6,882

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
07.18.09.323	77	Yates, John	231SNSL	--	--	--	S	--	--	6,964
07.18.11.234	51	Yates, John	211DKOT	--	--	--	S	--	--	6,908
07.18.26.442	52	Yates, John	211DKOT	--	--	--	S	--	--	6,842
07.18.29.311	78	Yates, John	231CHNL	--	--	--	S	--	--	6,864
07.19.02.344	79	Yates, John	231SNSL	--	--	--	S	--	--	6,898
07.19.08.333	66	Yates, John	313SADG	340R	--	--	S	--	--	6,616
07.19.12.142	80	Yates, John	231SNSL	--	--	--	S	--	--	7,128
07.19.15.131	67	Yates, John	313SADG	640R	--	--	S	--	--	6,897
07.19.24.422		Yates, John	313SADG	500R	--	--	--	--	--	6,901
07.19.31.411	53	Yates, John	221ZUNI	271R	--	--	S	--	--	6,504
07.19.33.423	68	Yates, John	313SADG	--	--	--	S	--	--	6,703
07.20.09.441		Cook, Len	211MVRD	--	6	--	S	47.47	10-21-80	6,350
07.20.10.311		Harker, Mazone	211MVRD	--	6	--	S	59.72	10-21-80	6,380
07.20.14.212A	54	Harker, Mazone	221ZUNI	390R	6.62	08-04-71	S	239.25	10-02-80	6,415
07.20.14.212B		Harker, Mazone	211DKOT	110	--	- -50	U	100.54	10-02-80	6,410
07.20.14.213	55	Harker, Mazone	211DKOT	103	48	--	H	88.16	10-02-80	6,415
07.20.20.411		Cook, Len	211DKOT	--	6	--	U	155.75	10-21-80	6,249
07.20.26.334	56	Cook, Len	211DKOT	--	6	--	S	178.77	10-08-80	6,350
07.20.27.112	57	Cook, Len	211DKOT	--	6	--	S	--	--	6,293
07.21.10.332	58	Hinkson, Everett	211DKOT	100R	6	--	S	44.60R	07- -75	6,073
07.21.26.111	59	Hinkson, Everett	211DKOT	40R	6	--	S	34.02	09-25-80	6,120
07.21.26.141A	60	Hinkson, Everett	211DKOT	130R	6	--	S	85.05	09-25-80	6,160
07.21.26.141B		Hinkson, Everett	211GLLP	--	6	--	U	47.17	09-25-80	6,160
07.21.36.222	61	Cox, R.L.	211DKOT	--	6	--	S	79.82	10-15-80	6,165
08.05.12.311	104	Laguna Pueblo	231CHNL	145	--	--	S	34.5	08-17-73	5,685
08.05.17.213	105	Laguna Pueblo	231CHNL	853	--	- -23	U	Flowing	07-19-75	5,838
08.06.20.333		Laguna Pueblo	313SADG	2,203	6.62	05-17-86	U	+368.2	05-23-86	6,025
08.08.25.423		Acoma Pueblo	313SADR	2,650	6.62	11-29-86	U	--	--	6,400
08.09.07.311		Acoma Pueblo	221ZUNI	330	6.75	--	S	206.00	11-30-78	6,785
08.10.24.221		Acoma Pueblo	221ZUNI	250	6.0	--	S	238.58R	04-25-84	6,841

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
08.10.24.311		Acoma Pueblo	221ZUNI	530	6	--	H	476.26	04-25-84	7,080
08.10.26.412		Acoma Pueblo	221ZUNI	--	6	--	S	256.25	11-13-78	6,896
08.10.35.141		King Bros.	221ZUNI	--	--	--	U	250.75	08-31-78	6,940
08.11.04.414		Arrosa, Pierre	313SADG	340R	--	--	S	--	--	7,185
08.11.06.233	69	Bright, Lewis	313SADG	520	--	--	S	499R	11-02-78	7,404
08.11.10.111		Porter, Bill	313SADG	250R	--	--	H	230R	07-15-81	7,105
08.12.19.334	81	Major, Buddy	231CHNL	600R	5.30	--	S,H	430.00	05-06-81	7,500
08.14.17.314		Ramah Navajos	211GLLP	361	6	01-12-35	P	235.00	- -71	7,306
08.14.27.213		Ramah Navajos	211GLLP	551	6.63	- -35	--	330.00	- -71	7,515
08.15.05.233		Pino, Jerry	211DKOT	820	5.56	--	S	210R	08-25-75	7,275
08.15.21.441		Ramah Navajos	211GLLP	441	8	- -59	--	312.00	- -71	7,480
08.15.27.311	70	Ramah Navajos	313SADG	3,590	8.62	05- -75	T	978R	05-14-75	7,478
08.15.27.342		Ramah Navajos	313SADG	446	8	07-28-54	P	344.00	- -71	7,445
08.15.30.300		Lewis, I.	211GLLP	325	--	- -70	--	--	--	7,350
08.16.22.342		Stevenson	211MVRD	265R	--	--	P	--	--	7,235
08.17.02.314		Zuni Pueblo	221ZUNI	1,175	6.63	--	S	411.90	05-30-79	7,380
08.17.30.332	82	Green, Bob	231CHNL	1,200R	--	--	H	--	--	7,110
08.18.22.111		Montaño Bros.	211DKOT	290R	6.63	--	S,U	51.00	02-10-81	7,300
08.18.22.121		Montaño Bros.	231CHNL	500R	6.63	- -79	U	--	--	7,310
08.18.22.123		Montaño Bros.	231CHNL	760R	6.63	--	H,S	--	--	7,320
08.18.24.221	83	Zuni Pueblo	231CHNL	1,460	5	05- -35	S	606R	05-22-35	7,219
08.19.04.321	84	Zuni Pueblo	231CHNL	590	6.63	12- -34	S	351R	12-17-34	6,885
08.19.12.211	85	Zuni Pueblo	231CHNL	1,115	6.63	--	S	35R	- -35	7,325
08.19.22.313	86	Zuni Pueblo	231CHNL	495	6.63	--	S	220.0	10-12-78	6,725
08.19.29.3312		Zuni Pueblo	313SADG	865	6.63	10-23-84	S	484.39	11-21-84	6,803
08.19.36.313	87	Montaño Bros.	231CHNL	200R	6.63	--	S	67.70	02-10-81	6,872
08.20.04.344	88	Zuni Pueblo	231CHNL	515	6	--	S	45.9	06-21-78	6,359
08.20.20.422		Zuni Pueblo	313SADG	Spring	--	--	I	--	--	6,300
08.20.21.144	71	Zuni Pueblo	313SADG	Spring	--	--	I	--	--	6,320
09.05.12.442	106	Laguna Pueblo	313SADG	1,729	6.63	- -64	U	+392.0	- -64	5,642
09.06.16.111		Laguna Pueblo	313SADG	2,650	6.62	07-03-86	U	+369.7	07-08-86	5,990

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
09.09.28.113		Baca, Pete	--	--	7.70	--	S	236.47	08-10-78	6,631
09.09.28.1344	72	Acoma Pueblo	313SADG	2,520	6.63	08-31-84	U	231.03	10-02-84	6,658
09.10.10.414		Mirabal, Alfred	313SADG	105	8.60	--	H,S	105.89	04-13-84	6,519
09.10.15.212		Mirabal, Alfred	313SADG	164	7	--	S	106.21	04-13-84	6,529
09.10.33.110		Mirabal, Alfred	313SADG	347	6	- -42	S	331.15	04-16-84	6,760
09.11.10.233		US Forest Service	400PCMB	127	7.20	--	S	119.38	07-14-81	7,404
09.12.12.113	1	Dunnington	000EXRV	Spring	--	--	--	--	--	7,600
09.14.01.244		Carter, Tiny	111MCCR	--	6	--	H,S	197.86	03-24-80	7,350
09.14.04.111		Bond, Vance	--	--	--	- -59	--	--	--	7,230
09.14.04.123		Bond, Vance	--	--	--	- -59	U	--	--	7,270
09.14.04.123A		Bond, Vance	--	--	--	--	H	252.00	--	7,270
09.14.04.221		Bond, Vance	--	--	--	- -59	U		--	7,270
09.14.05.112		El Morro Mon.	--	165	--	07-22-60	U	Dry	07-22-60	7,180
09.14.05.122		El Morro Mon.	--	136	--	07-26-60	D	Dry	07-26-60	7,180
09.14.05.212		El Morro Mon.	--	157	--	08-21-60	D	Dry	08-21-60	7,195
09.14.05.214		El Morro Mon.	231RCKP	222R	4	--	S	159.02	07-31-59	7,200
09.14.05.221		El Morro Mon.	110AVMB	196	--	08-09-60	--	178.00	08-09-60	7,205
09.14.05.344		El Morro Mon.	--	185	--	07-28-60	D	Dry	07-28-60	7,170
09.14.06.111		El Morro Mon.	110AVMB	200	6.0	10-07-61	R,P	163.90	03-26-80	7,162
09.14.06.313		El Morro Mon.	110AVMB	473	--	- -38	U	200R	- -38	7,230
09.14.06.421		El Morro Mon.	--	--	--	- -38	U	200.00	--	7,214
09.14.18.241		Worthen, O.B.	231RCKP	251R	--	12- -37	H,S	198.00	--	7,212
09.14.11.131		Carter, Tiny	231CHNL	1,640R	4	02- -59	--	130R	02-27-59	7,350
09.14.14.444		Carter, Tiny	110AVMB	--	6.50	--	U	44.86	01-05-81	7,236
09.14.24.312		Carter, Tiny	111MCCR	210R	6.50	--	S	88.16	03-26-80	7,342
09.14.26.421		--	110AVMB	--	6	--	U	24.96	03-25-80	7,356
09.14.29.314		Bond, Vance	211DKOT	--	4.50	--	S	--	--	7,158
09.14.29.431		--	211DKOT	--	6	--	S,H	94.70	03-25-80	7,172
09.15.01.141		Pettit, Gordon	110AVMB	213	6	- -50	S	165.37	03-26-80	7,153
09.15.01.311		Davis, Paul	231RCKP	300	6.62	07-18-75	S	150R	07-18-75	7,150

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
09.15.10.224		Clawson, Leslie	221ZUNI	180R	4	06-10-61	H	--	--	7,100
09.15.12.423		Jones, Frank	111MCCR	167R	--	--	H,S	--	--	7,135
09.15.14.421		Bond, Vance	110AVMB	170R	4	09- -58	S	120.00	07- -59	7,120
09.15.14.444		Baca, Tony	221ZUNI	--	4	--	S	116.75	03-25-80	7,126
09.15.22.123		Ramah Navajos	--	280	--	--	P	142.00	- -71	7,118
09.15.32.330		Eidal, R.M.	--	3,109	--	- -71	U	700DST	- -71	7,197
10.07.13.323		Weaver, Irwin	211DKOT	170	5.62	05-20-80	H	80R	05-20-80	6,200
10.07.13.344		Lopez, Christine	211DKOT	177	6	11-11-77	H	80R	11-11-77	6,165
10.07.14.421		Worley, Jack	211DKOT	103	5	09-10-79	H	72R	09-10-79	6,208
10.07.15.314		Baird, Chuck	211DKOT	220R	6	07-24-78	H,S	150R	07-24-78	6,227
10.07.18.143		Garnacha Ranch	211DKOT	243R	6.62	--	S	--	--	6,238
10.07.23.243		Gottlieb, Sidney	--	160	6	- -36	H	39.34	12-15-50	6,178
10.09.06.1422		Texaco Oil Co.	--	270	6.50	--	U	5.50	07-11-84	6,420
10.09.06.2311		Gunderson Oil Co.	231CHNL	122	6	--	U	7.27	07-11-84	6,415
10.09.10.341		--	211DKOT	90	6	--	U	64.57	04-12-84	6,365
10.09.10.433		--	--	120	5	--	U	49.27	04-12-84	6,460
10.09.15.221		--	110AVMB	52	6	--	U	36.19	04-12-84	6,335
10.09.17.113		Gottlieb, Sidney	110AVMB	76	6	- -45	S	46.09	03-13-84	6,439
10.09.21.222		Gottlieb, Sidney	111MCCR	70	6	- -49	S	47.56	02-01-84	6,399
10.09.21.444		Gottlieb, Sidney	224ENRD	80	6	- -49	S	46.94R	01-31-84	6,400
10.09.23.134		Gottlieb, Sidney	231CHNL	1,035	--	10-16-50	I	18.35	02-02-78	6,334
10.09.23.423	107	Horace Springs	--	Spring	--	--	I	--	--	6,276
10.09.25.324		Acoma Pueblo	313SADG	2,901	6.62	06-06-86	U	+147.1	06-11-86	6,280
10.09.26.224		Gottlieb, Sidney	--	100	6	- -36	S	8.74	01-31-84	6,275
10.09.26.433		Gottlieb, Sidney	231CHNL	965	14	--	S,I	30.18	02-09-84	6,347
10.09.29.132		Gottlieb, Sidney	--	80	7	- -44	S	65.90	03-13-84	6,455
10.09.31.324		Gottlieb, Sidney	--	165	7	- -49	S	93.13	03-13-84	6,484
10.10.03.3113		Small, Dwight	--	--	--	- -47	H,S	420R	04-04-84	6,769
10.10.03.423	108	Ojo del Gallo Sp.	313SADG	Spring	--	--	U	--	02-01-83	6,449
10.10.03.433A	109	San Rafael	313SADG	148	6	05- -52	P	25.79	11-06-57	6,458

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
10.10.03.4331		Mirabal, Miguel	110AVMB	43	6	--	U	26.46	06-29-84	6,470
10.10.10.321		Chavez, Dora	110AVMB	57	6	--	I	38.83	07-11-84	6,467
10.10.10.412		--	--	71	4	--	U	13.12	04-13-84	6,460
10.10.10.414		--	--	47	5	--	U	15.82	04-13-84	6,458
10.10.10.433		Chavez, Dora	313SADG	200	18	- -53	I	29.91	07-25-84	6,450
10.10.15.124		Ortiz, Ted	231CHNL	109	8	- -56	I	32.50	07-25-56	6,462
10.10.22.233		--	--	65	4	--	U	45.42	04-13-84	6,462
10.10.22.322		--	--	165	5	--	U	44.73	04-13-84	6,466
10.10.23.132		--	--	16	9	--	U	11.74	04-13-84	6,441
10.10.26.331	110	Mirabal, Monico	313SADG	216	16	12-31-51	I	30.05	08-14-84	6,454
10.10.27.333		Mirabal, Nabor	313SADG	165	16	04- -52	I	99.18	09-26-55	6,526
10.10.27.333A		Mirabal	313SADG	150	16	- -51	--	103.26	09-13-84	6,526
10.10.28.224		Griego, Benigno	313SADG	146	5	04-28-80	H	91.50	04-03-84	6,630
10.10.33.1333		Clymo, Donald	313SADG	383	4	--	U	336.58	04-03-84	6,750
10.10.34.1134		Garcia, Felix	313SADG	146	4.50	--	U	119.41	04-04-84	6,550
10.10.34.124		Anaya, Robert	313SADG	109	4	04-07-81	H	84.10	04-04-84	6,510
10.10.34.132		Archuleta, Chris	313SADG	135	4.50	- -82	U	114.66	04-04-84	6,550
10.10.34.1331		Garcia, Tom	--	185	6	- -49	H	133.85	04-04-84	6,570
10.10.34.141		Shulte, Arthur	313SADG	120	--	--	H	81.09	04-04-84	6,510
10.10.34.1423		Villa, Ben	313SADG	--	--	--	H	--	--	6,510
10.11.31.124		US Forest Service	400PCMB	200	7	--	S	194.25	07-28-81	7,808
10.11.17.231		US Forest Service	000EXRV	Spring	--	--	U	--	--	7,430
10.14.34.312	2	Bond, Vance	000EXRV	--	5.72	--	S,H	--	--	7,278
10.14.36.333		Carter, Tiny	111MCCR	--	4.58	--	S	210.22	01-05-81	7,328
10.15.05.123		Pettit, Gordon	110AVMB	102R	6.50	- -67	S	39.28	02-28-80	7,035
10.15.05.212		Sanchez Land Co.	110AVMB	59	4.50	--	U	42.01	04-08-80	7,058
10.15.13.332		--	111MCCR	--	6	--	S	77.28	04-07-80	7,179
10.15.14.422		--	111MCCR	--	6	--	S	77.85	04-07-80	7,185
10.15.17.414		Ramah Navajos	313SADG	150	8	- -51	P	619.00	01-18-75	7,100
10.15.20.122		Lambson, Alden	211DKOT	565R	4	05-28-61	S	--	--	7,070

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
10.15.24.100		--	--	388	--	- -67	--	88.00	- -71	7,150
10.15.36.324		--	111MCCR	--	6	--	S	144.26	03-25-80	7,137
10.15.36.332		Ramah L&C Co.	000EXRV	213	6	- -50	S	--	--	7,150
10.16.01.324		--	--	--	7	--	S	25.48	02-28-80	6,930
11.11.23.333		Bell, Bill R.	318YESO	980	6	- -52	S	431.33	07-29-81	7,305
11.03.06.221		Sohio Western	211DKOT	198	6.70	--	S	163.72	10-21-81	6,305
11.03.06.443		Sohio Western	211DKOT	120	5.57	--	S	36.59	10-21-81	6,195
11.04.09.134		Sohio Western	211DKOT	100R	--	--	H,S	--	--	6,181
11.04.14.111		Sohio Western	211DKOT	--	6.50	--	S	67.00	10-20-81	6,149
11.04.18.334		Sohio Western	110AVMB	65	6	--	U	61.56	05-10-74	6,085
11.04.20.132		Sohio Western	110AVMB	90R	4.50	--	S	49.60	10-21-81	6,060
11.05.01.124		Sohio Western	211DKOT	530	6.37	08- -75	U	367.87	10-19-81	6,265
11.05.01.211		Sohio Western	221MRSN	1,085R	6.37	11- -75	N	248R	06- -76	6,285
11.05.01.324		Sohio Western	221MRSN	1,010R	6.37	10- -75	N	126R	06- -75	6,230
11.05.12.122		Sohio Western	110AVMB	97	3.50	--	U	63.08	10-19-81	6,200
11.05.12.144		Sohio Western	221MRSN	1,000	6.37	10- -75	N	351.70	10-20-81	6,285
11.05.12.411		Sohio Western	221BRSB	540R	6.37	12- -75	N	284R	06- -76	6,170
11.05.12.343A		Sohio Western	221BRSB	535	6.37	08- -74	U	257R	08- -74	6,170
11.05.12.343B		Sohio Western	221BRSB	815	6.62	09-09-78	N	468.00	05-13-80	6,165
11.05.12.431		Sohio Western	221MRSN	--	--	--	N	--	--	6,165
11.05.12.432		Sohio Western	221MRSN	860	6.62	09-23-77	N	355R	- -77	6,160
11.05.12.441		Sohio Western	211DKOT	255	6.50	--	U	75.17	10-19-81	6,170
11.05.12.442		Sohio Western	221MRSN	800	6.62	08-03-78	N	475.00	06-04-80	6,180
11.05.13.112		Sohio Western	221BRSB	522R	6.37	10- -71	U	92.82	10-14-71	6,159
11.05.13.113		Sohio Western	221BRSB	510R	6.37	07- -74	U	212R	07- -74	6,240
11.05.14.241		Sohio Western	313SADG	3,390	--	02- -75	N	10R	03- -75	6,233
11.05.24.213		Sohio Western	221BRSB	390R	6.62	01- -71	U	161.76	05-10-74	6,162
11.05.27.322		Anaconda Co.	221BRSB	610R	--	--	N,P	--	--	6,002
11.06.09.423		Elkins	000EXRV	113	6.70	--	S	79.38	10-21-81	7,747
11.06.15.114		Sohio Western	000EXRV	--	--	--	U	--	--	7,680

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
11.06.15.134		Sohio Western	000EXRV	22	--	--	H,S	8.96	10-21-81	7,640
11.06.15.134A		Sohio Western	000EXRV	Spring	--	--	S	--	--	7,645
11.06.22.333		Encinal Spring	000EXRV	Spring	--	--	P	--	--	7,380
11.10.04.211	111	Evans, John	313SADG	315	12	05- -45	I	66.68	09-11-84	6,532
11.10.04.333		Dow Chemical Co.	313SADG	198	12	- -57	N	74.56	09-11-84	6,540
11.10.08.111		Milan, Salvador	313SADG	150	12	- -45	I	81.56	09-11-84	6,552
11.10.09.221	112	Stanley & Card	313SADG	480	20	08-24-45	I	68.41	09-11-84	6,535
11.10.16.121		Hanosh, Lee	313SADG	180	16	- -53	I	71.80	02-12-57	6,527
11.10.16.121A		Hanosh, Lee	313SADG	155	14	02- 45	--	77.15	01-14-74	6,527
11.10.26.321		City of Grants	110AVMB	110	16	- -46	P	28.60	02-12-57	6,465
11.10.26.321C	113	City of Grants	313SADG	--	16	--	--	22.00	06-26-58	6,740
11.10.27.241		Growers Assoc.	313SADG	158	16	- -52	N	25.39	08-14-84	6,480
11.11.05.232		Bell, Bill R.	318YESO	360R	7	04-04-51	S	326.87	07-15-81	6,998
11.11.12.411		Bell, Bill R.	313SADG	254	6	- -49	S	227.40	08-25-49	6,700
11.12.19.321		US Forest Service	400PCMB	Spring	--	--	P	--	--	8,425
11.13.18.343		US Forest Service	400PCMB	Spring	--	--	U	--	--	7,970
11.15.04.223		Clawson, Ronad	231CHNL	203	6.62	07-23-71	H	34R	07-23-71	7,600
11.15.05.123		Sanchez Land Co.	231CHNL	--	4.0	--	S	21.11	11-09-78	7,529
11.15.19.212		Sanchez Land Co.	110AVMB	49	16	--	S	12.10	11-02-78	6,956
11.15.20.114		Sanchez Land Co.	110AVMB	52	4	--	S	24.44	11-10-78	6,984
11.15.29.432		Sanchez Land Co.	231CHNL	173	4.50	--	U	93.94	04-09-80	7,265
11.15.30.141		Sanchez Land Co.	221MRSN	182	4	--	S	143.40	11-10-78	7,086
11.15.32.242		McDonald, Cliff	110AVMB	120R	--	--	H	--	--	7,130
11.15.32.434		Sanchez Land Co.	110AVMB	108	6.5	--	S	49.93	02-28-80	7,070
11.15.33.413		--	110AVMB	--	7	--	S	15.30	04-08-80	7,042
12.04.05.412		Exxon Minerals	221WSRC	840	5.25	09-29-70	N	633R	09-29-70	6,560
12.04.15.344		Exxon Minerals	221WSRC	950	5.25	11-05-70	N	452.40	03-03-77	6,640
12.04.21.423		Exxon Minerals	221WSRC	901	4.36	05-23-78	N	675R	05-23-78	6,680
12.04.21.423A		Exxon Minerals	221WSRC	891	4.36	05-19-78	N	670R	05-19-78	6,673
12.04.21.423B		Exxon Minerals	221WSRC	885	4.36	05-17-78	N	675R	05-17-78	6,682

Table 2.--Records of wells and springs in Cibola County--Continued

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
12.04.21.423C		Exxon Minerals	221WSRC	911	4.36	05-13-78	N	680R	05-13-78	6,685
12.04.22.311		Exxon Minerals	221WSRC	900	6.62	12-28-76	N	610R	12-28-76	6,610
12.04.22.311A		Exxon Minerals	221WSRC	900	2	12-04-76	N	590R	12-04-76	6,612
12.04.22.311B		Exxon Minerals	221WSRC	900	2	04-07-76	N	598R	12-07-76	6,616
12.04.23.311		Sohio Western	--	13	--	--	U	Dry	--	6,580
12.04.31.124		Sohio Western	221MRSN	1,140	6.62	04-20-77	N	814R	05-13-80	6,395
12.04.31.212		Sohio Western	221MRSN	1,220	6.62	10-06-77	N	400R	10-06-77	6,450
12.04.31.241		Sohio Western	221MRSN	1,116	7.75	08-21-79	N	585.00	06-04-80	6,400
12.04.31.312		Sohio Western	221MRSN	1,110	6.62	05-01-77	N	883.00	05-13-80	6,330
12.04.35.324		Sohio Western	211BRSB	400R	6.0	--	S	333.40	10-20-81	6,330
12.05.36.244		Sohio Western	221MRSN	1,140R	6.62	02-02-77	N	552.00	05-13-80	6,355
12.05.36.434		Sohio Western	221WSRC	1,120	6.62	04-21-71	N,S	207.20	05-05-71	6,295
12.05.36.441		Sohio Western	221MRSN	1,120R	6.37	12- -75	N	248R	12- -75	6,320
12.06.16.444		Sohio Western	211PNLK	495	5.63	--	S	464.32	10-22-81	8,310
12.06.23.131		Sohio Western	--	283	6	--	U	Dry	10-21-81	8,140
12.06.35.334		Sohio Western	211PNLK	325	11	--	S	121.35	10-22-81	7,935
12.07.03.434	3	US Forest Service	000EXRV	Spring	--	--	S	--	--	9,220
12.07.08.322	4	US Forest Service	000EXRV	Spring	--	--	P,S	--	--	8,940
12.07.10.414	5	US Forest Service	000EXRV	Spring	--	--	H,S	--	--	9,420
12.07.31.331	6	US Forest Service	000EXRV	Spring	--	--	S	--	--	9,690
12.08.13.143		US Forest Service	000EXRV	Spring	--	--	U	--	--	9,145
12.08.13.232		US Forest Service	000EXRV	Spring	--	--	U	--	--	9,165
12.08.14.143		US Forest Service	000EXRV	Spring	--	--	U	--	--	8,670
12.08.24.112	7	US Forest Service	000EXRV	Spring	--	--	S	--	--	9,020
12.08.25.111	8	US Forest Service	000EXRV	Spring	--	--	S,P	--	--	9,465
12.08.35.231	9	US Forest Service	000EXRV	Spring	--	--	--	--	--	8,810
12.08.36.234	10	US Forest Service	000EXRV	Spring	--	--	S	--	--	9,560
12.10.05.341A		Berryhill, Duane	313SADG	725	3.50	- -57	S	231.52	03-16-84	6,700
12.10.20.333A		Freas, Fred	313SADG	275	10	- -57	S	101.13	09-12-84	6,570
12.10.27.244		Morris, Tom A.	110AVMB	314	6	--	H,S	85.06	01-31-84	6,964

Table 2.--Records of wells and springs in Cibola County--Concluded

Well or spring number	Site number	Owner	Geologic unit	Depth of well (feet)	Casing diameter (inches)	Date completed	Use of water	Water level (feet)	Date water level measured	Altitude of land surface (feet)
12.10.27.333		Stanley, Dean	313SADG	551	16	12- -49	I	86.77	09-12-84	6,557
12.10.29.434		Card & Stanley	110AVMB	152	6.63	08- -44	I	76.32	09-12-84	6,552
12.10.30.421		Harding, Milton	313SADG	225	--	01-15-46	I	105.89	01-31-84	6,576
12.10.30.433	114	Freas, Fred	313SADG	--	6.00	--	--	--	--	6,570
12.11.09.221		Stearns, L.G.	313SADG	500	20	- -45	I	109.36	08-14-84	6,649
12.11.10.431		Johns & Ross	313SADY	248	14	01- -45	I	102.07	02-27-46	4,635
12.11.14.213		Berryhill, Duane	111MCCR	115	--	03-30-49	--	83.14	08-14-84	6,605
12.11.15.341	115	Freas, Edward	310GLRT	232	14	08- -46	I	84.05	09-11-84	6,627
12.11.23.333	116	Roundy, G.P.	313SADG	--	16	--	--	--	--	6,620
12.11.25.313		Harmon & Reid	313SADG	365	18	05- -46	I	133.29R	03-06-84	6,592
12.12.17.143		Morrow, Jim	110AVMB	--	--	--	H	124.53	07-15-81	7,550
12.12.17.200	117	--	313SADG	--	--	--	--	--	--	--
12.15.29.412		Old Bond Ranch	231CHNL	--	5	--	S	14.19	06-17-80	7,850

Table 3.--Water-quality analyses for wells and springs in Cibola County

EXPLANATION

Well or spring number: wells and springs in this table are located to the nearest 10-acre plot as described in the text. All wells and springs are located north of the New Mexico Base Line and west of the New Mexico Principal Meridian.

Geologic unit: 110AVMB, alluvium; 112LGUN, Laguna Basalt; 122SPRS, Spears Formation (Chapin, 1971); 211MNCS, Mancos Shale; 211MVRD, Mesaverde Group; 211CRVC, Crevasse Canyon Formation; 211GLLP, Gallup Sandstone; 211DKOT, Dakota Sandstone; 221ZUNI, Zuni Sandstone; 221BRSB, Brushy Basin Member of Morrison Formation; 231CHNL, Chinle Formation; 231SNSL, Sonsela Sandstone Bed of Petrified Forest Member of Chinle Formation; 313SADG, San Andres Limestone and Glorieta Sandstone; 318GLRT, Glorieta Sandstone; 318YESO, Yeso Formation; 400PCMB, Precambrian; 000EXRV, extrusive rocks.

Other abbreviations: µS/cm, microsiemens per centimeter at 25 degrees Celsius; deg C, degrees Celsius; mg/L, milligrams per liter; µg/L, micrograms per liter; <, less than; M, presence of material verified but not quantified; fed-fld, fixed end-point titration, field; --, no data.

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Site number	Date of sample	Geologic unit	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L)	Solids, sum of constituents, dissolved (mg/L)
04.06.12.111		05-02-84	231CHNL	4,300	7.0	--	1,200	790	3,300
04.06.12.300		04-21-55	231CHNL	909	9.7	--	66	0	--
04.07.07.111		05-13-81	211MVRD	--	--	18.5	1,200	970	2,100
04.09.01.341		03-17-81	211DKOT	3,300	7.6	12.0	700	440	2,300
04.09.09.131		03-02-81	211CRVC	1,600	7.5	12.0	400	0	1,200
04.11.06.111		04-27-81	211CRVC	425	7.5	14.0	18	0	270
04.11.08.124A		04-29-81	211CRVC	1,000	8.0	14.0	120	0	680
04.11.11.213		05-05-81	211GLLP	1,190	8.7	17.0	25	0	730
04.12.02.133		04-27-81	112LGUN	1,300	7.0	12.5	280	52	860
04.12.11.342		04-28-81	211CRVC	1,000	7.6	13.5	68	0	570
04.15.04.423		12-16-80	122SPRS	350	8.3	15.5	120	0	230
04.16.10.331A		12-17-80	211MVRD	533	8.1	--	76	0	320
04.16.10.331B		12-17-80	211MVRD	846	7.7	11.0	150	0	520
04.17.03.324B		10-14-80	211MVRD	1,900	8.2	13.5	20	0	1,100
04.17.04.233		10-13-80	211MVRD	1,550	8.3	14.0	23	0	1,000
04.17.08.121		10-14-80	211MVRD	600	8.1	15.0	17	0	330
04.18.03.442		10-31-80	211MVRD	800	7.8	13.0	260	27	440
04.18.05.144B		11-18-80	211MVRD	350	7.6	14.0	150	0	230
05.04.05.142	89	06-09-81	313SADG	2,200	7.0	19.0	1,500	1,300	2,000
05.05.10.333A	90	06-09-81	231CHNL	2,400	7.4	18.5	1,100	480	1,900
05.05.10.333B	91	06-09-81	231CHNL	3,800	7.1	19.0	1,600	1,100	3,200
05.05.16.443	92	06-05-81	231CHNL	2,400	7.3	17.0	1,000	390	1,700
05.05.25.1223		04-15-54	231CHNL	2,480	--	--	30	0	--
05.06.31.242	93	06-10-81	231CHNL	829	9.1	21.0	7	0	510
05.07.34.433		05-20-81	000EXRV	504	8.3	19.0	200	17	280
05.07.35.334		05-20-81	211DKOT	450	7.6	15.0	180	2	250
05.08.11.214		06-10-81	211DKOT	1,500	7.6	17.0	540	320	1,100
05.08.32.111		03-03-81	211DKOT	4500	7.3	13.0	2,200	1,900	4,200
05.09.26.412		03-18-81	211GLLP	1,700	8.1	15.0	210	0	1,200
05.10.12.113		08-29-78	211GLLP	588	7.2	14.0	240	4	360

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Site number	Date of sample	Geologic unit	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L)	Solids, sum of constituents, dissolved (mg/L)
05.10.12.141		04-04-81	211GLLP	227	7.5	14.0	87	0	120
05.10.27.234		05-06-81	211CRVC	2,150	7.5	12.5	500	59	1,500
05.10.35.223		04-28-81	211CRVC	1,800	7.5	13.0	270	0	1,300
05.11.15.242		09-06-78	211MVRD	888	7.8	17.0	97	0	550
05.11.26.323		09-06-78	211GLLP	1,550	7.6	16.5	650	490	1,200
05.12.01.224		08-30-78	211CRVC	741	7.6	15.0	220	15	470
05.12.04.112	28	08-31-78	211DKOT	632	8.1	15.0	51	0	420
05.12.13.141	29	08-30-78	211DKOT	733	8.0	13.0	93	0	450
05.12.20.133		08-30-78	211GLLP	1,000	8.2	13.0	13	0	600
05.12.25.344		08-31-78	211MVRD	1,130	7.4	13.0	20	0	680
05.12.27.313		08-31-78	211GLLP	543	7.8	16.5	130	0	320
05.13.15.333		08-31-78	211GLLP	670	8.0	16.0	90	0	410
05.13.18.113		12-03-80	211MVRD	1,150	8.8	15.5	8	0	670
05.14.06.334		12-18-80	211MVRD	406	8.2	14.0	110	0	240
05.14.15.334	30	12-03-80	211DKOT	450	7.9	17.0	120	0	260
05.15.16.223	31	12-03-80	211DKOT	290	8.2	15.0	91	0	220
05.15.19.444		12-04-80	211MVRD	1,130	8.0	14.0	400	150	620
05.15.26.133		12-16-80	211MVRD	330	8.7	14.5	19	0	230
05.15.28.431		12-16-80	211MVRD	500	9.3	13.0	7	0	330
05.15.31.222A		12-04-80	211MVRD	340	8.9	15.0	11	0	240
05.16.19.141	32	11-19-80	211MNCS	700	8.0	13.0	120	0	370
05.16.21.242	33	11-19-80	211DKOT	1,000	8.4	13.0	7	0	590
05.16.36.431		12-17-80	211MVRD	1,300	7.9	11.0	510	140	990
05.17.05.232	11	11-13-80	211MVRD	450	9.1	15.0	9	0	310
05.17.05.444	12	11-06-80	211MVRD	525	9.3	15.0	5	0	360
05.17.06.333	13	11-06-80	211MVRD	327	8.1	12.0	42	0	200
05.17.07.333	14	11-20-80	211MVRD	350	7.3	14.0	140	14	210
05.17.09.223	15	11-06-80	211MVRD	465	8.1	14.0	47	0	330
05.17.10.344	16	11-20-80	211MVRD	700	8.0	13.0	13	0	390
05.17.13.132A	34	11-19-80	211DKOT	650	8.7	13.0	9	0	370

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Site number	Date of sample	Geologic unit	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L)	Solids, sum of constituents, dissolved (mg/L)
05.17.14.443	35	11-19-80	211DKOT	650	8.7	16.0	4	0	370
05.17.29.131		10-10-80	211MVRD	550	7.4	15.0	100	0	320
05.17.31.211		10-20-80	211MVRD	450	7.5	12.5	42	0	260
05.18.01.233	17	11-05-80	211MVRD	350	9.3	15.0	11	0	220
05.18.08.223	18	11-12-80	211MVRD	340	8.1	20.0	150	0	220
05.18.10.342	19	11-05-80	211MVRD	414	7.2	15.0	160	0	240
05.18.12.212	20	11-05-80	211MVRD	336	8.2	15.0	110	0	200
05.18.13.222	21	11-06-80	211MVRD	351	8.0	14.0	140	17	210
05.18.13.444	36	11-19-80	211DKOT	950	8.3	14.0	12	0	630
05.18.15.111	22	12-02-80	211MVRD	456	7.8	17.0	200	40	270
05.18.15.444	23	12-02-80	211MVRD	532	7.8	13.0	120	0	310
05.18.24.324	24	01-07-81	211MVRD	500	8.0	14.0	200	66	250
05.19.04.444B	37	11-12-80	211DKOT	500	9.1	17.0	6	0	330
05.19.07.334		10-14-80	211MVRD	371	7.0	13.0	160	0	210
05.20.24.122		09-24-80	211CRVC	500	7.6	15.0	230	48	280
05.20.29.344	62	09-26-80	313SADG	1,350	8.4	23.0	490	210	750
05.21.10.112B	38	10-01-80	211DKOT	500	7.8	15.0	170	35	230
05.21.35.321	63	09-24-80	313SADG	1,300	7.6	16.5	310	200	630
06.05.26.132	94	08-29-62	313SADG	4,630	6.9	20.5	2,300	1,900	4,200
06.08.34.333A		05-21-81	211DKOT	5,000	7.3	10.5	2,400	2,000	4,100
06.08.34.341		01-22-61	110AVMB	4,920	6.8	--	2,500	2,000	4,500
06.10.06.121	39	08-28-78	221ZUNI	539	7.2	15.0	250	7	310
06.10.07.232	40	08-28-78	211DKOT	1,170	7.4	14.0	400	110	730
06.10.20.114	41	08-29-78	211DKOT	1,680	7.2	14.0	640	240	1,200
06.10.20.411		08-29-78	110AVMB	1,890	7.4	14.0	710	370	1,400
06.11.02.412		08-31-78	211DKOT	1,290	7.6	14.0	230	22	850
06.11.34.113		08-28-78	110AVMB	539	7.8	16.5	210	29	300
06.11.34.322		08-31-78	211MVRD	404	7.7	14.0	160	25	230
06.12.01.311	42	09-06-78	221ZUNI	500	8.0	15.0	110	0	310
06.12.13.421	43	08-31-78	211DKOT	477	7.8	14.0	170	22	290

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Site number	Date of sample	Geologic unit	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L)	Solids, sum of constituents, dissolved (mg/L)
06.17.13.342		01-06-81	211DKOT	470	8.5	14.0	100	0	280
06.17.16.331		11-13-80	211DKOT	450	8.0	14.0	170	0	310
06.17.19.131	44	11-14-80	211DKOT	350	8.2	13.0	43	0	220
06.17.20.442		11-13-80	211DKOT	400	8.2	14.5	140	0	270
06.17.27.123	25	01-06-81	211MVRD	1,300	8.8	14.0	24	0	720
06.17.30.111		11-06-80	211DKOT	418	7.6	13.0	150	0	260
06.17.30.214		11-13-80	211DKOT	455	8.2	14.5	180	0	300
06.17.30.311		11-07-80	211DKOT	380	8.1	15.0	140	0	270
06.17.31.313	26	11-20-80	211MVRD	600	7.2	13.0	180	0	320
06.17.33.212		11-21-80	110AVMB	320	7.5	14.0	160	0	180
06.17.34.433B	27	11-06-80	211MVRD	1,510	7.8	13.0	290	0	980
06.18.10.232	73	10-29-80	231CHNL	629	9.0	17.0	--	--	--
06.18.27.433		11-12-80	000EXRV	383	7.6	16.0	140	0	270
06.18.30.214		10-31-80	211MVRD	421	7.8	14.5	150	0	270
06.19.01.131	74	11-06-80	231CHNL	520	8.1	17.0	81	0	360
06.19.13.413	75	11-05-80	231CHNL	930	8.4	20.0	53	0	640
06.19.16.113	45	10-29-80	211DKOT	655	8.0	14.0	220	10	390
06.19.24.311		11-05-80	211DKOT	2,200	7.8	15.0	1,300	1,100	2,100
06.19.24.421	46	11-05-80	211DKOT	480	8.2	15.0	190	19	290
06.19.29.231	47	11-11-80	211DKOT	2,200	8.0	17.0	460	250	1,700
06.20.04.233	48	10-15-80	211DKOT	2,570	7.0	14.0	830	400	2,000
06.20.10.213		10-01-80	211DKOT	2,130	7.1	15.5	690	280	1,600
06.20.14.412		07-14-46	211DKOT	2,860	--	11.5	1,100	710	2,300
06.20.31.132		10-21-80	211DKOT	1,800	8.8	14.5	55	0	1,200
06.21.10.222		09-30-80	211DKOT	900	8.5	18.0	370	220	570
07.04.11.431		05-28-75	231CHNL	4,370	--	16.0	--	--	--
07.04.13.114	95	05-19-81	110AVMB	826	7.8	16.0	380	110	450
07.04.15.222	96	05-19-81	110AVMB	3,100	--	17.0	2,000	1,700	3,000
07.04.25.111	97	05-19-81	313SADG	3,010	6.9	16.0	1,600	1,200	2,300
07.04.29.421	98	06-09-81	110AVMB	679	8.0	19.0	150	0	420

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Site number	Date of sample	Geologic unit	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L)	Solids, sum of constituents, dissolved (mg/L)
07.05.06.221A	99	03-26-81	231CHNL	1,500	9.1	20.0	11	0	980
07.05.36.333	100	06-09-81	231CHNL	1,100	7.2	19.0	440	140	810
07.06.10.443B	101	03-26-81	231CHNL	1,200	8.6	17.0	23	0	770
07.06.18.424	102	03-26-81	231CHNL	950	8.4	15.0	38	0	610
07.06.22.331	103	03-26-81	231CHNL	2,300	8.7	19.0	18	0	1,600
07.07.28.114		01-28-66	221ZUNI	852	8.2	--	200	14	--
07.09.09.334		08-09-78	211MVRD	608	7.2	12.0	260	48	360
07.10.20.414		08-04-78	221ZUNI	682	--	12.0	340	85	400
07.10.22.112		09-05-78	221ZUNI	856	7.5	20.0	410	140	500
07.11.02.311	64	04-29-81	313SADG	160	8.4	17.0	49	0	130
07.12.13.244	65	09-06-78	313SADG	761	7.4	14.0	270	44	480
07.12.21.433		11-30-78	221ZUNI	259	8.5	16.0	37	0	160
07.16.06.314	49	01-06-81	211DKOT	1,400	8.8	15.0	17	0	830
07.16.21.342		07-29-53	211GLLP	2,070	--	14.5	680	370	1,500
07.17.16.214	50	11-04-80	211DKOT	1,300	7.8	15.0	500	210	1,000
07.17.30.121	76	10-29-80	231CHNL	624	9.0	12.0	6	0	380
07.18.09.323	77	11-04-80	231SNSL	900	9.2	19.0	6	0	590
07.18.11.234	51	10-29-80	211DKOT	701	7.8	17.0	280	40	450
07.18.26.442	52	10-29-80	211DKOT	697	8.6	14.0	8	0	410
07.18.29.311	78	10-30-80	231CHNL	600	9.2	20.0	4	0	410
07.19.02.344	79	10-30-80	231SNSL	690	8.3	19.0	6	0	360
07.19.08.333	66	11-06-80	313SADG	1,180	7.4	14.0	530	230	760
07.19.12.142	80	10-30-80	231SNSL	950	9.1	16.0	9	0	650
07.19.15.131	67	11-06-80	313SADG	1,100	7.3	24.0	510	210	770
07.19.31.411	53	11-11-80	221ZUNI	750	7.6	16.0	260	0	550
07.19.33.423	68	11-05-80	313SADG	1,000	7.2	18.0	480	200	730
07.20.10.311		10-21-80	211MVRD	437	7.4	16.0	200	0	260
07.20.14.212A	54	10-21-80	221ZUNI	476	7.5	14.5	61	0	280
07.20.14.213	55	10-02-80	211DKOT	500	7.6	15.5	190	0	310
07.20.26.334	56	10-21-80	211DKOT	1,150	7.2	16.0	380	59	760

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Site number	Date of sample	Geologic unit	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L)	Solids, sum of constituents, dissolved (mg/L)
07.20.27.112	57	10-02-80	211DKOT	1,850	--	15.0	870	610	1,300
07.21.10.332	58	01-10-80	211DKOT	1,650	6.9	15.5	600	410	1,100
07.21.26.111	59	09-25-80	211DKOT	1,400	7.3	15.5	540	250	1,000
07.21.26.141A	60	09-25-80	211DKOT	1,400	7.8	--	460	300	950
07.21.36.222	61	10-15-80	211DKOT	1,290	7.5	12.0	530	250	880
08.05.17.213	105	04-04-74	231CHNL	82,800	7.1	--	13,000	13,000	52,200
08.09.07.311		11-30-78	221ZUNI	893	7.6	13.0	390	130	630
08.10.24.221		08-02-78	221ZUNI	922	7.5	15.0	440	230	600
08.10.24.311		11-08-78	221ZUNI	682	7.6	20.0	290	60	430
08.10.26.412		11-13-78	221ZUNI	727	7.8	13.0	320	110	470
08.11.06.233	69	11-02-78	313SADG	342	7.9	12.0	140	0	200
08.12.19.334	81	05-06-81	231CHNL	270	8.3	15.0	44	0	170
08.15.27.311	70	05-14-75	313SADG	1,010	8.3	--	410	190	370
08.16.22.342		01-08-81	211MVRD	900	9.5	15.0	6	0	550
08.17.02.314		07-28-72	221ZUNI	3,400	8.0	23.0	2,100	1,800	--
08.17.30.332	82	12-04-80	231CHNL	800	7.8	7.0	130	0	600
08.18.24.221	83	08-31-79	231CHNL	700	8.3	--	18	0	530
08.19.04.321	84	08-01-72	231CHNL	740	8.8	18.0	10	0	455
08.19.12.211	85	08-01-72	231CHNL	990	8.8	18.0	10	0	620
08.19.22.313	86	08-01-72	231CHNL	730	9.0	22.0	5	0	430
08.19.36.313	87	02-10-81	231CHNL	553	7.7	--	210	71	280
08.20.04.344	88	09-08-72	231CHNL	1,050	7.5	18.0	480	210	695
08.20.21.144	71	06-19-79	318GLRT	1,050	7.0	22.0	520	250	760
09.05.12.442	106	11-10-64	231CHNL	18,000	6.7	31.5	2,200	710	14,000
09.09.28.113		08-10-78	221ZUNI	556	7.4	16.0	230	57	330
09.09.28.1344	72	09-21-84	313SADR	1,300	6.9	41.5	510	190	850
09.12.12.113	1	07-14-81	000EXRV	308	7.0	6.0	130	0	170
09.14.06.111		01-05-81	221ZUNI	440	8.3	14.0	120	0	250
09.15.01.141		04-25-59	110AVMB	430	7.8	--	110	0	280
10.07.23.243		12-15-50	211DKOT	2,310	--	--	900	650	1,800

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Site number	Date of sample	Geologic unit	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L)	Solids, sum of constituents, dissolved (mg/L)
10.09.06.442		05-13-58	000EXRV	3,110	--	10.5	960	470	2,300
10.09.17.113		12-08-50	110AVMB	6,840	--	--	2,400	2,000	5,500
10.09.23.134		12-08-50	231CHNL	754	--	16.0	94	0	470
10.09.23.423	107	06-26-62	--	1,200	7.9	--	380	170	780
10.09.26.433		08-10-78	231CHNL	1,665	7.6	20.0	120	0	410
10.10.03.423	108	06-06-84	313SADG	1,490	7.1	14.5	570	240	1,100
10.10.03.433A	109	08-17-63	313SADG	1,070	7.3	16.5	430	170	700
10.10.26.331	110	10-13-64	313SADG	1,180	7.4	17.0	470	220	760
10.11.31.124		07-28-81	400PCMB	250	7.3	14.0	120	8	170
10.14.34.312	2	01-05-81	112LGUN	455	7.8	14.5	140	0	260
11.05.24.213		05-14-71	221BRSB	1,750	7.5	18.0	100	0	1,100
11.10.04.211	111	07-29-68	313SADG	1,240	7.8	18.0	560	330	--
11.10.09.221	112	06-26-62	313SADG	1,080	7.3	13.5	480	250	760
11.10.26.321C	113	12-15-58	313SADG	1,880	7.0	22.5	680	300	1,400
11.11.05.232		07-15-81	318YESO	500	7.5	15.0	240	0	260
11.12.19.321		07-15-81	400PCMB	80	5.7	10.5	43	0	69
11.15.32.242		01-07-81	110AVMB	800	8.5	6.0	68	0	440
12.07.03.434	3	07-14-81	000EXRV	190	7.7	11.0	78	0	130
12.07.08.322	4	07-14-81	000EXRV	127	8.5	12.5	54	2	86
12.07.10.414	5	07-14-81	000EXRV	129	7.9	12.0	50	0	100
12.07.11.330		08-29-62	000EXRV	257	6.6	7.0	90	42	150
12.07.31.331	6	07-13-81	000EXRV	111	7.4	14.0	40	0	100
12.08.24.112	7	07-16-81	000EXRV	130	7.0	9.0	50	0	97
12.08.25.111	8	07-15-81	000EXRV	160	7.0	14.0	63	0	--
12.08.35.231	9	07-15-81	000EXRV	106	7.7	8.0	33	0	97

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Site number	Date of sample	Geologic unit	Specific conductance (µS/cm)	pH (standard units)	Temperature (deg C)	Hardness (mg/L as $CaCO_3$)	Hardness, noncarbonate (mg/L)	Solids, sum of constituents, dissolved (mg/L)
12.08.36.234	10	07-13-81	000EXRV	117	8.1	14.0	43	0	100
12.10.30.433	114	10-21-44	313SADG	919	--	--	410	160	590
12.11.15.341	115	05-06-47	313SADG	1,340	--	--	560	270	910
12.11.23.333	116	03-10-65	313SADG	1,460	7.2	--	640	350	--
12.12.17.200	117	08-30-64	313SADG	647	7.4	--	320	87	380

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate fet-fld (mg/L as HCO_3)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Silica, dis-solved (mg/L as SiO_2)	Boron, dis-solved (µg/L as B)	Iron, dis-solved (µg/L as Fe)
04.06.12.111	330	83	580	18	--	1,900	130	2.6	12	1,100	900
04.06.12.300	--	--	--	--	120	120	68	1.2	5.2	--	--
04.07.07.111	270	130	190	5.2	--	1,300	17	.40	18	350	4,400
04.09.01.341	170	67	500	5.7	--	1,400	30	.30	10	160	520
04.09.09.131	110	30	270	3.8	--	500	28	.60	13	120	1,300
04.11.06.111	5.9	.90	98	1.4	--	19	12	.80	15	100	290
04.11.08.124A	32	9.1	200	1.9	--	220	39	1.1	11	380	110
04.11.11.213	7.4	1.7	270	.90	--	140	18	4.2	8.8	310	70
04.12.02.133	65	29	180	3.0	--	400	27	.90	16	340	10
04.12.11.342	17	6.2	210	2.5	--	75	21	3.0	11	650	70
04.15.04.423	33	8.8	40	1.9	--	16	7.0	.30	14	80	130
04.16.10.331A	22	5.1	89	1.8	--	68	5.7	.70	14	100	20
04.16.10.331B	43	11	120	2.3	--	200	9.5	.60	10	130	20
04.17.03.324B	6.4	.90	380	2.3	--	520	8.9	1.4	8.6	420	110
04.17.04.233	7.6	.90	330	1.4	--	530	14	.40	8.8	400	80
04.17.08.121	5.5	.70	120	1.3	--	44	10	.60	9.9	120	1,000
04.18.03.442	50	32	57	8.7	--	66	63	.60	25	150	20
04.18.05.144B	47	8.9	14	.70	--	21	15	.70	22	70	10
05.04.05.142	360	150	21	3.5	--	1,300	18	.50	16	110	6,800
05.05.10.333A	120	200	230	8.9	--	890	25	.50	11	320	2,200
05.05.10.333B	400	140	450	22	--	1,800	77	2.7	8.9	780	7,800
05.05.16.443	120	180	230	5.5	--	740	18	.60	6.6	370	22,000
05.05.25.1223	--	--	--	--	1,320	240	27	1.4	15	--	--
05.06.31.242	2.2	.30	190	3.8	--	110	37	1.2	20	640	30
05.07.34.433	36	26	26	4.0	--	31	26	.70	23	70	<10
05.07.35.334	38	21	22	2.9	--	19	18	.60	22	50	90
05.08.11.214	120	59	140	5.1	--	610	22	.50	11	310	20
05.08.32.111	490	230	440	5.3	--	2,800	67	.20	14	200	1,500
05.09.26.412	60	14	340	2.5	--	640	8.2	.80	11	160	20
05.10.12.113	63	21	35	2.6	--	45	19	.30	27	120	20

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate fet-fld (mg/L as HCO_3)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Silica, dis-solved (mg/L as SiO_2)	Boron, dis-solved (µg/L as B)	Iron, dis-solved (µg/L as Fe)
05.10.12.141	30	2.9	11	2.2	--	1.6	3.4	2.8	13	30	10
05.10.27.234	150	30	310	3.0	--	640	53	.60	11	100	290
05.10.35.223	83	16	370	3.6	--	620	38	.40	12	90	390
05.11.15.242	26	7.7	170	2.6	--	150	16	.80	13	200	40
05.11.26.323	170	54	120	3.6	--	680	25	.30	14	100	440
05.12.01.224	57	20	75	2.6	--	160	9.7	.90	18	270	280
05.12.04.112	12	5.2	130	2.5	--	130	7.3	1.4	11	250	90
05.12.13.141	23	8.6	130	1.9	--	110	9.7	2.0	13	360	90
05.12.20.133	3.6	1.0	230	1.7	--	110	9.5	1.0	11	280	220
05.12.25.344	4.9	1.8	260	2.0	--	110	26	3.4	8.7	690	50
05.12.27.313	31	13	68	.80	--	39	18	.80	22	110	80
05.13.15.333	25	6.6	110	4.5	--	73	18	.80	32	180	70
05.13.18.113	2.2	.50	260	2.7	--	94	7.1	1.7	8.0	350	50
05.14.06.334	27	9.9	48	3.7	--	25	14	.60	16	180	120
05.14.15.334	31	11	46	3.5	--	22	9.1	.40	20	70	20
05.15.16.223	24	7.5	42	4.0	--	18	9.0	.40	17	80	50
05.15.19.444	110	31	78	5.4	--	95	120	.40	29	50	30
05.15.26.133	5.3	1.3	87	1.3	--	17	4.2	.40	12	90	390
05.15.28.431	2.2	.30	140	1.2	--	2.9	9.0	3.1	1.9	440	30
05.15.31.222A	3.6	.60	87	2.1	--	16	6.3	.50	11	150	20
05.16.19.141	4.7	26	100	1.6	--	59	4.1	.80	14	180	270
05.16.21.242	2.3	.20	240	1.2	--	78	5.4	7.5	8.8	920	30
05.16.36.431	110	57	140	2.8	--	430	14	.40	17	120	30
05.17.05.232	2.6	.60	120	1.2	--	45	7.0	.90	8.7	310	30
05.17.05.444	1.6	.30	140	.90	--	49	4.7	.90	9.5	190	30
05.17.06.333	11	3.6	56	2.1	--	19	5.4	.40	16	70	150
05.17.07.333	41	10	16	1.9	--	34	7.8	.80	24	--	<10
05.17.09.223	14	2.9	110	2.3	--	43	5.2	.50	14	140	1,800
05.17.10.344	4.2	.60	150	1.0	--	74	5.5	.60	9.4	260	20
05.17.13.132A	2.8	.60	140	1.0	--	50	4.3	1.6	13	500	420

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Calcium, dis- solved (mg/L as Ca)	Magne- sium, dis- solved (mg/L as Mg)	Sodium, dis- solved (mg/L as Na)	Potas- sium, dis- solved (mg/L as K)	Bicar- bonate fet-fld (mg/L as HCO_3)	Sulfate, dis- solved (mg/L as SO_4)	Chlo- ride, dis- solved (mg/L as Cl)	Fluo- ride, dis- solved (mg/L as F)	Silica, dis- solved (mg/L as SiO_2)	Boron, dis- solved (µg/L as B)	Iron, dis- solved (µg/L as Fe)
05.17.14.443	1.3	0.10	150	0.50	--	34	2.5	1.1	12	320	<10
05.17.29.131	30	6.0	79	2.4	--	72	11	.70	13	160	60
05.17.31.211	13	2.4	80	2.2	--	22	7.6	.60	13	110	280
05.18.01.233	3.4	.70	80	1.3	--	22	12	.50	8.2	140	210
05.18.08.223	42	10	20	1.3	--	19	16	.40	23	50	20
05.18.10.342	47	10	22	2.0	--	22	15	.40	22	50	30
05.18.12.212	31	7.8	24	2.1	--	28	6.9	.50	22	40	<10
05.18.13.222	40	9.0	15	1.8	--	32	10	.60	25	30	10
05.18.13.444	3.7	.60	230	1.2	--	170	33	3.7	9.4	620	100
05.18.15.111	62	11	16	1.8	--	28	29	.50	21	180	<10
05.18.15.444	32	9.3	67	2.5	--	42	10	.60	13	170	50
05.18.24.324	57	13	15	1.8	--	27	37	.50	22	20	50
05.19.04.444B	1.9	.20	130	.80	--	30	8.3	.50	9.1	130	220
05.19.07.334	50	8.4	8.8	.80	--	9.9	13	.60	27	50	<10
05.20.24.122	73	11	7.9	1.7	--	23	32	.40	27	60	10
05.20.29.344	140	34	69	9.7	--	250	60	2.0	15	140	6,900
05.21.10.112B	50	12	18	2.1	--	24	24	.40	18	50	10
05.21.35.321	54	42	75	10	--	290	60	1.5	14	140	17,000
06.05.26.132	600	190	430	27	410	2,600	140	1.9	9.9	1,400	0
06.08.34.333A	470	300	420	2.5	--	2,600	49	.10	8.0	130	8,400
06.08.34.341	540	290	--	--	610	2,800	90	.50	10	--	--
06.10.06.121	56	26	23	2.6	--	39	2.7	1.1	12	140	130
06.10.07.232	99	36	110	3.6	--	280	11	.50	17	120	400
06.10.20.114	170	52	170	3.2	--	560	16	.60	18	160	420
06.10.20.411	190	58	180	3.5	--	760	12	.60	19	160	2,500
06.11.02.412	58	21	190	3.9	--	430	3.5	1.1	12	200	400
06.11.34.113	67	10	34	1.8	--	50	9.8	.30	14	130	40
06.11.34.322	52	8.4	22	1.2	--	32	10	.50	18	120	20
06.12.01.311	28	8.9	69	3.9	--	54	11	.60	28	130	40
06.12.13.421	49	12	35	2.5	--	39	34	.40	31	30	50

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate fet-fld (mg/L as HCO_3)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Silica, dis-solved (mg/L as SiO_2)	Boron, dis-solved (µg/L as B)	Iron, dis-solved (µg/L as Fe)
06.17.13.342	24	10	56	3.8	--	39	7.6	0.30	32	50	70
06.17.16.331	39	17	40	5.2	--	37	12	.30	34	40	30
06.17.19.131	12	3.1	67	2.4	--	21	5.8	.30	13	90	110
06.17.20.442	33	15	34	5.1	--	27	9.0	.30	35	40	70
06.17.27.123	7.0	1.7	270	1.5	--	180	20	5.0	8.1	540	130
06.17.30.111	38	13	31	3.6	--	32	6.1	.20	27	60	400
06.17.30.214	42	19	30	4.9	--	34	12	.30	34	40	40
06.17.30.311	32	14	31	5.5	--	35	5.8	.30	36	60	10
06.17.31.313	46	15	48	2.7	--	41	7.1	.30	20	110	70
06.17.33.212	30	20	8.5	4.1	--	.8	2.9	2.1	13	130	40
06.17.34.433B	83	19	230	3.2	--	380	23	.20	15	560	<10
06.18.10.232	1.3	<.00	150	2.4	--	35	11	.60	12	200	410
06.18.27.433	34	14	32	4.3	--	35	5.7	.30	37	50	30
06.18.30.214	37	13	29	3.5	--	37	6.5	.40	38	40	10
06.19.01.131	26	3.9	100	6.5	--	71	12	.60	10	140	70
06.19.13.413	17	2.5	200	3.7	--	240	16	.30	18	260	140
06.19.16.113	60	17	47	4.0	--	78	30	.50	28	120	30
06.19.24.311	370	100	130	6.0	--	1,300	16	.60	12	300	120
06.19.24.421	46	18	23	5.0	--	62	7.0	.30	27	80	10
06.19.29.231	120	39	410	5.3	--	1,000	18	.70	9.8	440	40
06.20.04.233	230	62	330	5.6	--	1,100	19	.50	17	240	5,100
06.20.10.213	190	53	250	6.2	--	810	12	.50	17	170	3,700
06.20.14.412	310	87	--	--	520	1,300	18	.20	--	--	--
06.20.31.132	16	3.6	390	12	--	670	47	.70	5.7	970	160
06.21.10.222	99	31	49	3.2	--	240	31	.40	20	120	40
07.04.11.431	--	--	300	15	--	--	320	--	--	860	--
07.04.13.114	96	33	25	5.6	--	100	13	.90	15	160	70
07.04.15.222	590	130	150	11	--	1,800	130	1.1	20	510	2,800
07.04.25.111	390	160	140	6.5	--	1,200	140	1.0	17	510	470
07.04.29.421	17	26	98	3.2	--	110	22	.80	19	390	50

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Calcium, dis- solved (mg/L as Ca)	Magne- sium, dis- solved (mg/L as Mg)	Sodium, dis- solved (mg/L as Na)	Potas- sium, dis- solved (mg/L as K)	Bicar- bonate fet-fld (mg/L as HCO_3)	Sulfate, dis- solved (mg/L as SO_4)	Chlo- ride, dis- solved (mg/L as Cl)	Fluo- ride, dis- solved (mg/L as F)	Silica, dis- solved (mg/L as SiO_2)	Boron, dis- solved (µg/L as B)	Iron, dis- solved (µg/L as Fe)
07.05.06.221A	3.4	0.70	390	0.30	--	140	53	1.8	8.5	1,200	90
07.05.36.333	110	40	100	6.2	--	330	28	1.3	17	380	250
07.06.10.443B	5.6	2.3	310	.30	--	80	17	1.8	13	1,200	80
07.06.18.424	8.1	4.4	240	.30	--	61	11	1.5	14	1,000	20
07.06.22.331	6.2	.50	560	.40	--	730	150	.60	9.9	610	360
07.07.28.114	50	19	--	--	230	220	16	.60	15	--	0
07.09.09.334	67	22	31	2.6	--	53	33	.40	28	130	60
07.10.20.414	100	23	23	2.6	--	80	5.5	.20	12	40	80
07.10.22.112	85	48	31	3.3	--	150	9.3	.60	12	70	210
07.11.02.311	14	3.4	21	1.5	--	8.5	.80	1.5	30	10	130
07.12.13.244	83	16	59	3.5	--	110	41	1.0	27	170	270
07.12.21.433	12	1.7	44	2.7	--	18	10	.30	6.2	50	290
07.16.06.314	5.0	1.2	310	1.5	--	250	57	4.4	6.7	560	50
07.16.21.342	180	56	--	--	380	820	10	.20	10	--	--
07.17.16.214	110	54	160	1.8	--	500	6.1	.80	11	260	2,100
07.17.30.121	1.9	.20	150	.70	--	50	8.2	1.2	9.8	370	20
07.18.09.323	2.1	.30	210	1.4	--	180	15	1.3	11	640	250
07.18.11.234	74	23	44	12	--	130	4.2	.30	12	60	1,700
07.18.26.442	2.7	.40	160	.60	--	77	32	1.0	5.6	300	140
07.18.29.311	1.6	.10	160	1.6	--	81	13	.60	9.1	180	940
07.19.02.344	2.0	.30	140	6.1	--	30	12	.40	10	120	290
07.19.08.333	150	38	57	6.8	--	270	41	.60	17	100	2,500
07.19.12.142	3.3	.20	230	1.1	--	260	19	2.2	9.9	1,000	270
07.19.15.131	140	39	53	6.3	--	290	39	.60	16	120	4,800
07.19.31.411	73	18	89	3.4	--	180	11	.40	16	40	40
07.19.33.423	130	38	54	6.9	--	260	45	.60	16	110	8,100
07.20.10.311	67	8.0	14	2.5	--	23	2.9	.40	16	50	320
07.20.14.212A	18	3.8	80	2.0	--	59	7.8	.30	10	100	20
07.20.14.213	60	10	46	4.5	--	1.7	8.2	.20	10	60	160
07.20.26.334	94	35	110	4.1	--	290	14	.50	16	200	4,700

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Potassium, dissolved (mg/L as K)	Bicarbonate fet-fld (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Fluoride, dissolved (mg/L as F)	Silica, dissolved (mg/L as SiO_2)	Boron, dissolved (µg/L as B)	Iron, dissolved (µg/L as Fe)
07.20.27.112	230	72	64	4.9	--	740	18	0.30	20	150	4,000
07.21.10.332	160	49	130	5.1	--	650	12	.30	12	220	120
07.21.26.111	150	40	130	3.1	--	490	25	.70	16	160	60
07.21.26.141A	120	40	130	2.7	--	520	21	.70	17	140	220
07.21.36.222	140	43	82	2.2	--	420	9.2	.60	17	140	700
08.05.17.213	700	370	12,000	--	10	940	28,000	--	--	2,800	--
08.09.07.311	83	44	64	3.5	--	250	10	.40	12	130	20
08.10.24.221	110	39	39	3.0	--	260	9.6	.40	12	80	60
08.10.24.311	70	28	35	3.2	--	130	7.1	.60	14	150	160
08.10.26.412	69	37	33	3.8	--	170	9.4	.60	10	100	1,300
08.11.06.233	33	13	16	2.7	--	16	6.5	.30	19	60	<10
08.12.19.334	11	3.9	43	3.3	--	14	9.0	.20	27	30	40
08.15.27.311	110	34	60	4.0	250	300	19	.50	--	0	3,500
08.16.22.342	1.9	.30	210	.70	--	160	6.6	1.9	7.7	380	50
08.17.02.314	560	160	170	6.0	260	2,000	74	.40	--	0	30
08.17.30.332	37	9.4	160	2.5	--	230	6.7	.60	11	290	<10
08.18.24.221	6.4	.50	170	1.0	--	210	5.9	.70	11	--	50
08.19.04.321	2.0	1.2	180	2.0	300	70	16	1.2	--	820	80
08.19.12.211	2.0	1.2	210	2.0	300	170	12	4.0	--	1,200	430
08.19.22.313	2.0	.00	160	3.0	250	100	14	2.0	--	720	80
08.19.36.313	68	10	25	2.3	--	23	54	.20	16	30	<10
08.20.04.344	130	38	57	4.0	330	300	35	.60	--	M0	20
08.20.21.144	140	41	54	5.8	--	310	32	.50	15	--	<10
09.05.12.442	320	330	4,100	59	1,770	4,300	3,700	2.9	14	3,500	--
09.09.28.113	53	23	32	2.0	--	94	10	.50	14	140	40
09.09.28.1344	140	39	88	7.4	--	290	72	.70	18	280	720
09.12.12.113	39	7.3	9.2	5.2	--	10	4.0	.50	21	10	28
09.14.06.111	30	11	41	2.9	--	16	18	.30	31	40	20
09.15.01.141	31	7.9	--	--	200	24	23	.20	29	--	0
10.07.23.243	180	110	--	--	300	1,000	57	1.2	20	--	--

Table 3.--Water-quality analyses for wells and springs in Cibola County--Continued

Well or spring number	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate fet-fld (mg/L as HCO_3)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Silica, dis-solved (mg/L as SiO_2)	Boron, dis-solved (µg/L as B)	Iron, dis-solved (µg/L as Fe)
10.09.06.442	210	110	--	--	590	940	270	1.0	41	--	--
10.09.17.113	330	380	--	--	470	2,800	750	.70	30	--	--
10.09.23.134	22	9.4	--	--	320	120	12	.80	8.4	--	--
10.09.23.423	90	37	--	--	250	290	90	.80	33	--	10
10.09.26.433	27	13	100	2.1	--	100	7.8	.50	18	110	50
10.10.03.423	150	47	130	6.6	--	400	110	.50	18	460	9
10.10.03.433A	110	39	--	--	320	250	46	--	19	--	0
10.10.26.331	120	41	75	5.0	300	270	80	.60	20	270	--
10.11.31.124	33	8.5	8.3	1.1	--	22	4.9	1.0	26	10	57
10.14.34.312	36	12	43	2.0	--	16	13	.30	26	30	30
11.05.24.213	21	12	370	3.0	480	470	16	1.3	13	--	--
11.10.04.211	150	46	--	--	290	370	41	.50	19	--	--
11.10.09.221	140	31	62	4.0	280	300	34	.60	28	--	0
11.10.26.321C	180	57	--	--	470	500	130	.20	15	--	--
11.11.05.232	55	25	7.2	1.2	--	7.0	13	.50	12	10	110
11.12.19.321	12	3.1	4.4	.80	--	1.0	1.1	.30	20	10	150
11.15.32.242	15	7.3	150	1.0	--	31	52	.60	11	280	20
12.07.03.434	19	7.3	7.9	1.0	--	1.0	2.2	.40	37	0	82
12.07.08.322	17	2.9	4.2	1.0	--	1.0	1.6	.60	26	0	66
12.07.10.414	12	4.8	6.7	1.4	--	1.0	1.4	.50	41	0	29
12.07.11.330	26	6.1	6.2	1.4	58	5.2	45	.20	30	40	50
12.07.31.331	10	3.6	5.8	3.9	--	2.0	1.1	.50	47	0	38
12.08.24.112	13	4.2	5.7	2.5	--	4.0	2.7	.40	34	0	46
12.08.25.111	13	7.4	5.6	2.0	--	<1.0	1.5	.50	58	0	40
12.08.35.231	7.7	3.3	6.5	3.7	--	1.0	1.2	.60	45	0	28

Table 3.--Water-quality analyses for wells and springs in Cibola County--Concluded

Well or spring number	Calcium, dis-solved (mg/L as Ca)	Magne-sium, dis-solved (mg/L as Mg)	Sodium, dis-solved (mg/L as Na)	Potas-sium, dis-solved (mg/L as K)	Bicar-bonate fet-fld (mg/L as HCO_3)	Sulfate, dis-solved (mg/L as SO_4)	Chlo-ride, dis-solved (mg/L as Cl)	Fluo-ride, dis-solved (mg/L as F)	Silica, dis-solved (mg/L as SiO_2)	Boron, dis-solved (µg/L as B)	Iron, dis-solved (µg/L as Fe)
12.08.36.234	9.5	4.7	5.5	2.9	--	1.0	2.4	0.60	45	0	68
12.10.30.433	98	39	--	--	300	190	33	--	--	--	--
12.11.15.341	150	45	--	--	350	380	59	.40	--	--	--
12.11.23.333	180	48	--	--	350	400	69	.60	16	--	100
12.12.17.200	82	29	14	1.0	290	87	13	.60	8.1	90	10

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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WATER-RESOURCES INVESTIGATIONS REPORT 94-4178
Geology - PLATE 1

Baldwin, J.A., and Rankin, D.R., 1995
Hydrogeology of Cibola County, New Mexico

EXPLANATION

Qs	Spring deposits
Qal	Alluvium, surficial deposits, eolian deposits
Qb	Basalt, undifferentiated flows, ash, cinder cones
Ql	Landslides
QTb	Basalt, undifferentiated
QTv	Mount Taylor volcanics
QTi	Igneous intrusive
Tb	Bidahochi Formation
Ts	Spears Formation
Kmv	Mesaverde Group, undivided
Kcc	Crevasse Canyon Formation
Kg	Gallup Sandstone
Kmd	Mancos Shale, Dakota Sandstone, undifferentiated
Km	Mancos Shale
Kd	Dakota Sandstone
Ju	Jurassic, undifferentiated. Includes Zuni Sandstone, Bluff Sandstone, Summerville Formation, Todilto Limestone, and Entrada Sandstone
Jm	Morrison Formation
Jz	Zuni Sandstone
Jb	Bluff Sandstone
Js	Summerville Formation
Jt	Todilto Formation
Je	Entrada Sandstone
℞c	Wingate Sandstone and Chinle Formation, undifferentiated
Psa	San Andres Limestone
Pg	Glorieta Sandstone
Py	Yeso Formation
Pa	Abo Formation
IP	Pennsylvanian rocks, undifferentiated
p€	Precambrian rocks, undifferentiated

CONTACT -- Dashed where approximate, dotted where inferred

FAULT -- Dashed where approximate, dotted where covered or inferred. Ball on downthrown side

MONOCLINE -- Dashed where approximate, dotted where inferred

* CINDER CONE

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GEOLOGIC MAP OF CIBOLA COUNTY, NEW MEXICO

by
Joe A. Baldwin and Dale R. Rankin
1995